Edward Barlow

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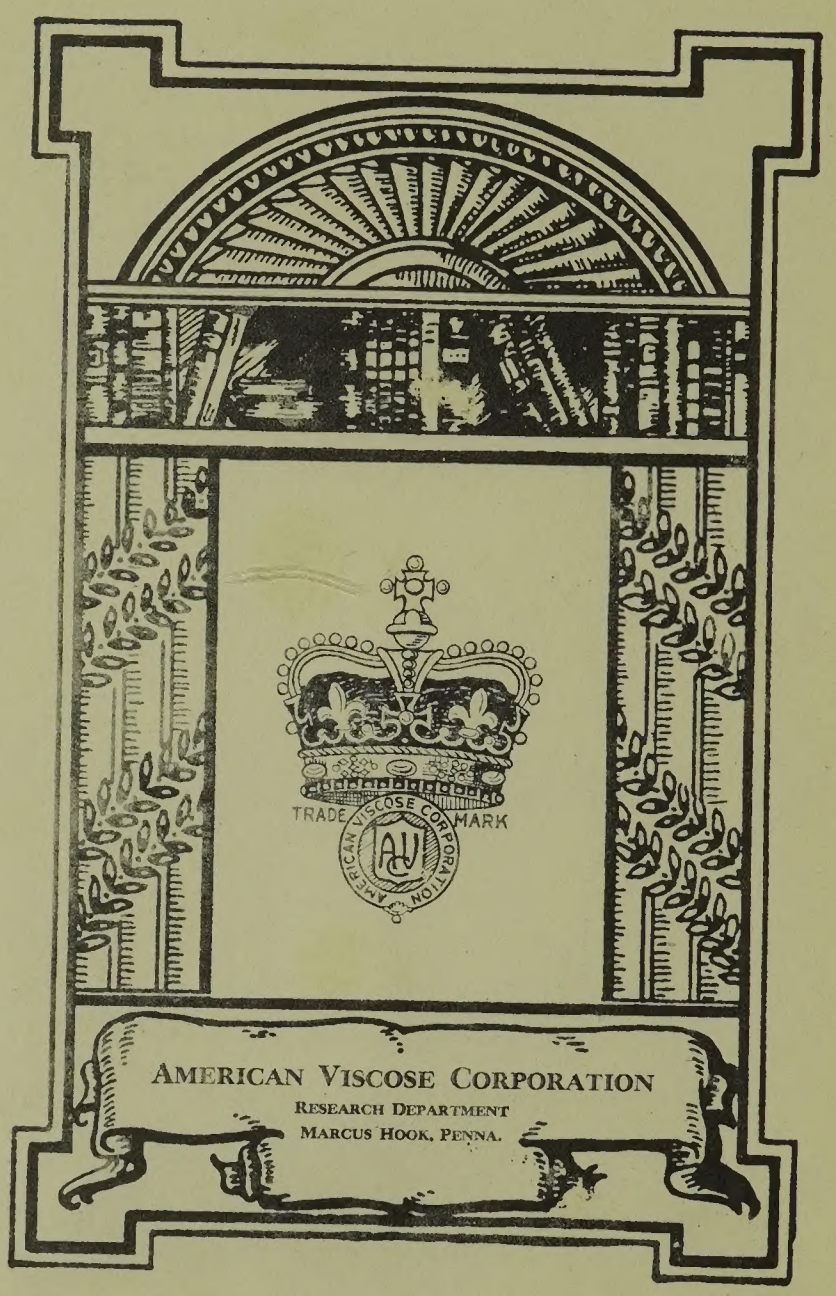

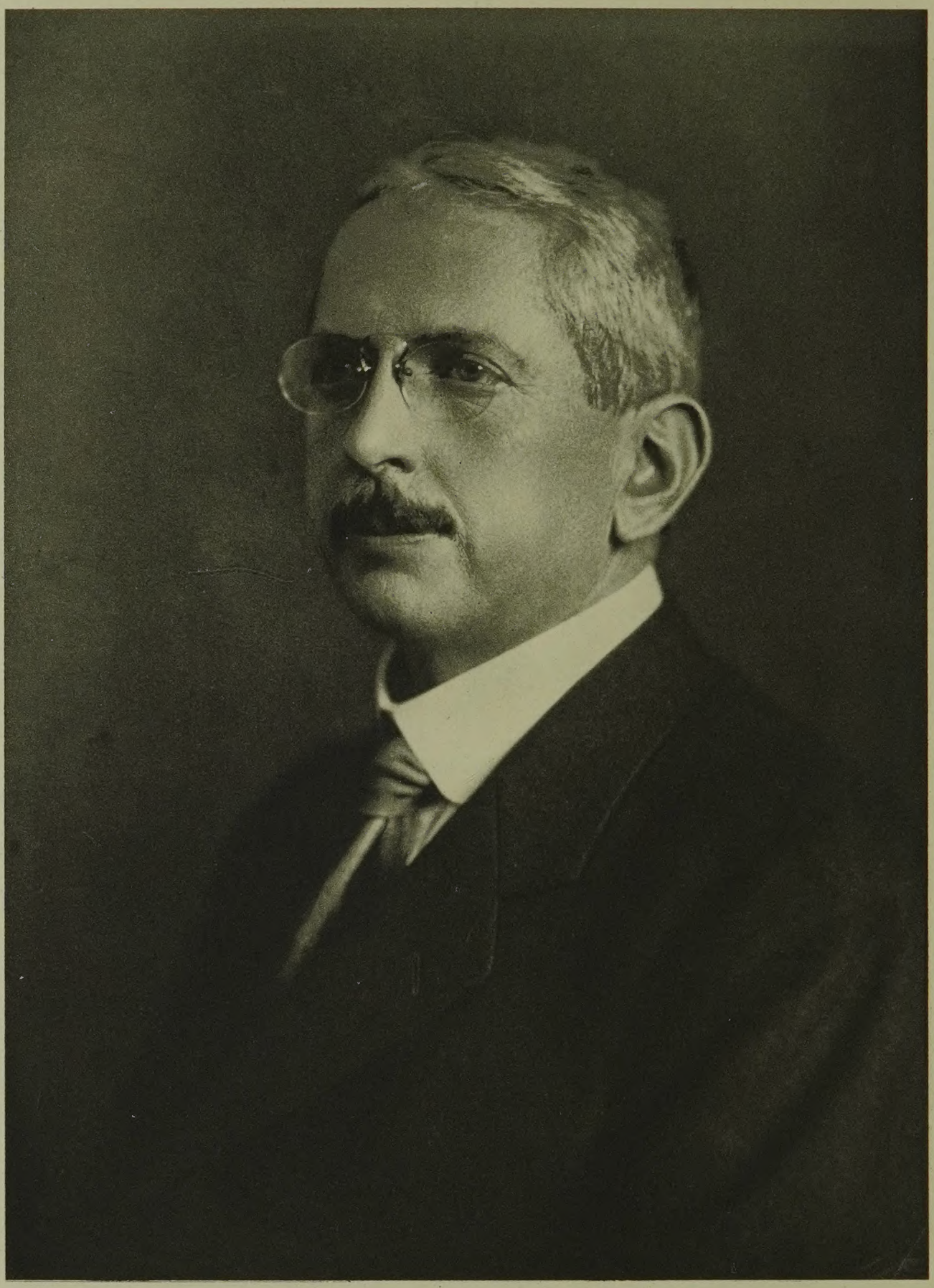

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TRANSACTIONS

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OF

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TRANSACTIONS OF THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS.

SOME PROFESSIONAL OBLIGATIONS.

By President M. C. WHITAKER.

Read at the Troy Meeting, June 17, 1914.

Chemical engineering as an organized profession is comparatively new, although many men have been engaged in this class of work since the beginning of large-scale manufacture. Since the organization of this Institute, various definitions have been given to outline the scope of our professional activities, many schemes have been suggested to improve the training of our apprentices, some advances have been made towards standardization in our engineering practice, a code defining the ethical standards of our profession has been formulated and adopted, and we have shown our aims, with some results, in constructive patent reform. Work of such a character is of the greatest importance, and is far in advance of that heretofore undertaken by any other organization in our field. It can never be regarded as completed, and the best thought and effort of well-constituted committees will continue to be given to advancement along these lines, with great resultant benefit to the profession.

There comes a time, however, in the life history of every organization or enterprise, when the greatest advancement and improvement may be made by a process of introspection. It would seem to the speaker that chemical engineers might now, with great profit to themselves and benefit to the profession, submit to a process of self-analysis. Obviously it would be out of time and place to attempt now a profound or philosophical analysis of our internal personal relations and aims, but it is hoped that by reference to a

few of the more fundamental points, we may thereby catalyze some productive reactions.

Chemical engineering must, sooner or later, come to be recognized as the leader among the engineering professions. Its interests are larger and more varied, and its scope is greater and more intimately related to social and industrial progress, than that of any one or all of the other branches of applied science. Manufacturing output in the United States, which in money value is already almost equal to the largest single productive interest, will be dependent in some, if not in all, of its steps upon the chemical engineer. The burden of the development of the industrial processes and the operation of plants will fall upon him, and naturally the rewards of success and the odium of the failures will be his. The realization of the opportunities of such a profession, so full of brilliant promise and great possibilities, will depend in a large measure upon the breadth of view adopted in the acceptance of our responsibilities.

A voluble assertion of our importance will not give us the power to master our calling. Professional prestige, in the engineering field at least, is built upon achievement. Achievement worthy of the dignity of a profession cannot be built upon independent work, the spectacular results of a few individuals, or the hit-and-miss strokes of fortune. It must be based upon a consistent development of and by a body of able progressive men, and be based upon years of unselfish constructive coöperation, in which each member contributes his share, and in turn, draws freely from the common store.

The legal, the medical, and the clerical professions have devised for themselves some form of legal protection. The engineering professions, on the other hand, are subject to no form of external control, and may become self-developing or self-effacing according to the wisdom of the policies adopted in their direction and development, and the positiveness and value of their achievements. Merit, after all, is the only measure of success in engineering, and all failures, and even doubtful results, are promptly charged off against the profession.

The civil engineer may design and build a bridge. During construction, his work is open and in full view of the public, and his colleagues. There is not a single feature of his purpose, his design, or his materials of construction which is not common knowledge to anyone who takes the trouble to look at his work, or read any of the numerous articles published during its progress. Even the lay public

may be interested and pay their tribute to the man behind the work. The finished bridge stands in public as a monument to the power and ability of the builder and the profession he represents.

The mechanical engineer may design and build a wonderful machine. There is no secret about any of the features. His colleagues, the public, or anyone may study and criticise his work, accept and profit by his suggestions, and ingenious features, or may avoid his mistakes. The mechanical engineer has profited by the successes and failures of his predecessors in the art, and his successors, in their turn, will build better as a result of his work.

So it is with the mining and the electrical engineer. Each works with a full knowledge of what has gone before; each contributes his share to the advancement of his art, and the standing of the profession is enhanced because of his contributions.

The chemical engineer, on the other hand, works in unappreciated silence behind factory walls. He is not building a monument which invites public approval, though he may be making a product of equal value and more wonderful if it were understood. The details of his work are carefully guarded, and he is even denied the stimulus of public interest in his achievements. His designs, materials and methods often lack the helpful suggestions of his fellow engineers. He may repeat at great expense the mistakes previously made by his neighbor, or may fail to avail himself of well-worked-out methods which are not known to him on account of lack of proper exchange of professional knowledge. If he is secretive, it comes as a result of environment and conditions. This secretiveness often becomes a habit, and is assumed to be a necessity. At times this habit is extended either unconsciously or accidentally to ludicrous limits. For example, note how difficult it is to find the professional or business connections of a chemist or chemical engineer. Surely there is nothing about this which should be concealed. On the contrary, good would result both to him and his employer, by having his connections and field of activity well known. The directories of all other engineering societies contain valuable information about the professional activities of their membership, while our directories in many cases carefully disguise even the business addresses of our members.

The chemical engineer's efficiency in the production of successful results is reduced to a minimum, because of a lack of liberal professional coöperation, while civil, mechanical, electrical, and other

engineers are steadily improving their professional efficiency, by a systematic exchange of principles and practices, and a selective action to carry forward the good methods and reject the bad ones. We of the chemical engineering profession are harboring conditions which retard or frequently even prevent professional progress.

When the work of the chemical engineer is not open to public view, his productive efforts not understood, and therefore not appreciated, his achievements cautiously guarded, his business connections withheld from the directories of his societies, and absolutely no record of his professional activities is made available, is it any wonder the lay public usually think of him as a druggist?

If one traces the life history of the development of the Chemical Engineer, it will be found that we have some bad traditions to overcome. Our alchemist forefathers cultivated secretiveness, mystery and even deception. These dark art traditions are openly professed to-day in some of our factories, while in others they remain in latent evidence.

With these adverse conditions and traditions in existence, it would seem that the chemical engineers are confronted with an important problem which intimately concerns the progress and development of the profession. Inefficiency and loss of prestige are bound to result from unsupported individual effort. Coöperation is essential to substantial engineering development. This coöperation comes about naturally in other engineering professions, and it will have to come, if not naturally then by force of necessity, in ours.

Every failure in design, every fatal accident, every industrial disease, every fire or explosion in a chemical works, every commercial insuccess is an indictment against the chemical engineering profession. Cause and effect in bridge failures, dam failures, boiler explosions, railroad and steamship wrecks, are freely discussed in conventions and journals, for the benefit of the interested profession. These open and frank discussions disarm public criticism on the one hand, and on the other, place before all members of the profession, most impressive and profitable lessons in what not to do.

The chemical engineer in such cases, apparently guided by his ancient traditions, or his environment controlled habits, as no other motive seems discernible, often secretes the facts not only from the public, but also from his professional associates. Such secretiveness always arouses public suspicion. The interests of humanity may be sacrificed, and the profession, without the knowledge of what has

happened, may go blundering into the same disaster again and again. These costly disasters are not even recorded as experience outside of the factory walls in which they occur.

Have the chemical engineers discussed or even heard of the causes leading to the failure of the coke plant at Bethlehem; the cause and effect of the explosion in the artificial leather factory at Detroit; the lessons to be drawn from the recent fire in the Mallinckrodt works in St. Louis; the cause and effect of the failure of a large gas holder at Philadelphia; the cause or remedy of the large number of industrial diseases in some of our plants; the complete failure of this or that piece of equipment or method of installation?

Do the affected or afflicted chemical engineers seek the assistance of their associates and professional colleagues in determining the cause, and suggesting the remedy for such disasters?

If the cause and the remedy are determined are the facts made public?

Think of the benefit which would come to our profession and to humanity and industry in general, from frank authoritative discussion of these and many other problems which come within the experience of every chemical engineer. The discussion of the defective design, or material, or installation of chemical engineering appliances is a thing which would be of inestimable benefit, not only to other engineers, but also ultimately to the producers of the appliances. Negative results can be of no possible value to those industries which have developed them, but if they were published or discussed, they would become of the greatest importance to future engineering progress. Why should they be jealously guarded and secreted and the progress of this profession thereby blocked?

The question as to what knowledge the manufacturer should disclose for public use, and what should be kept within the factory walls is one which may be settled by the rule of reason, but never settled by yielding to the inclinations of our natural environment and our ancestral traditions. When it becomes clear that these conditions are blockading engineering progress and our own professional development, it will not be simply a duty, but an obligation, for every chemical engineer to apply this rule of reason.

Property value might safely be accepted as the basis for determining what should, and what should not be disclosed. Manufacturers and chemical engineers would not be expected to give out unprotected information of direct property value, any more than

civil engineers would be expected to publish their working drawings before the contracts were awarded, or the mechanical engineer be expected to give away the appliances in which he had invested his time and his money. Such a policy would result in commercial anarchy, and tend to destroy industrial stability, and with it the dependent professions.

Fortunately it is very often the knowledge having the least property value which, when collected and classified, possesses the greatest professional value. Negative results can usually be disclosed without loss, and they form the most substantial basis for engineering development.

On the other hand, the publication of the failure of a design, a material, or a process, would invite constructive thought from others, which might turn a failure into a success, or suggest to our young investigators researches which would definitely establish or disprove the scientific validity of the principles involved.

The interests of humanity demand that industrial diseases, industrial accidents, and improvements in working conditions be openly and frankly discussed, in order that the combined effort of all minds be brought to bear on the needed solutions. Proper publicity in all bad or doubtful cases, would do much to soften the hearts of the financial control, and at the same time independently enlist the services of the physiological chemists, the medical researchers, the mill designers, and many minds in our own profession, which is most seriously indited.

We have all heard the statement, by members of this profession, that there are no adequate textbooks or handbooks in chemical engineering, of the same standard of excellence as those existing in mechanical engineering, for example. Such books, in any engineering field, are the results of compilations and classifications of approved matter from current technical journals, and Society proceedings, and it is inevitable that they will be large or small, dense or rare, profound or superficial, in direct proportion to the current available material.

If we secrete our information, or fail to publish our researches, hoard our knowledge and avoid the full and frank discussion of our industrial problems, we are bound to reap the negative rewards. Our books will not represent the sum of a profession's knowledge, but instead, the comparatively small, laboriously attained work of one or a very few individuals.

This Institute, representing as it does the leading organization devoted exclusively to developing the technical interests of the chemical engineers, and enhancing the prestige and value of that profession, should be the first to consider all obstacles to the accomplishment of its purpose. Our profession is built upon the applications of a science of the most infinite and varied detail. The mastery of modern chemistry requires a highly developed mind, and one which should be fully qualified to attack and solve with ease the general problems of policy in the development of the profession. Our organization is new, and the problems are large and numerous. Most careful consideration must be given to the direction of our energies into those channels in which we shall find the most productive returns. We have no time to waste on philosophical quibbling or fussy arguments. If self-analysis shows that the indictment of narrowness is valid, and that the best interests of our profession will be served, as I think they will, by a more active interest in public questions, such as the so-called conservation movement, public service control, corporate regulation, finanacing of industrial enterprises, etc., then we should study and discuss these problems in our meetings and proceedings.

If chemical engineering education is twenty or thirty years behind the methods and efficiency of mechanical and electrical engineering training, as I think it is, and its improvement is being blocked by the dogmatic teaching that chemical manufacture is nothing more than enlarged laboratory practice, it then becomes evident that even more strenuous efforts will be required, from this Institute and its hard-working committees, to produce the desired results.

If, as I firmly believe, our professional progress is being seriously blocked by an unjustified and unjustifiable veil of secrecy or mystery drawn around our experiences, our needs, our achievements, and our professional activities, the removal of this obstacle to our advancement becomes an obligation upon each constitutent member of the chemical engineering profession, and particularly upon the Institute of Chemical Engineers.

CHEMICAL ENGINEERING LABORATORIES,
COLUMBIA UNIVERSITY,
NEW YORK

DISTRIBUTION OF INDUSTRIAL OPPORTUNITIES.

By GEO. OTIS SMITH, Director of the United States Geological Survey.

Read at the Philadelphia Meeting, December 2, 1914.

Four constituents enter into the reaction that we term industry. Two of these, brain and brawn, are organic compounds and two are perhaps to be regarded as inorganic—money and material. None of these components is wanting here in the United States, and in fact their abundance affords the best reason for an optimistic outlook upon the present industrial situation. While in nowise overlooking the large importance of labor and engineering skill and capital as factors in the establishment of new enterprises or the expansion of old industries, I wish to address my remarks chiefly to the subject of the distribution of the raw material that is no less essential to a nation's industry.

In the highly differentiated system of production and commerce, the place factor has assumed large influence. The growth of transportation agencies makes the whole world tributary to both producer and consumer, with the result that keen competition tends to localize and specialize production. By way of contrast, think of the industrial conditions of a century ago. Our grandmothers were in a way chemical engineers. Yet, to them, for instance, potash presented no international problem, but as soap makers they utilized that home supply that gave the material its common name. In those days as a poet has said:

> "Home was a factory, life a trade,
> And Mother a Captain of Industry."

To-day, facility of transportation has changed all this, and industrial opportunities distribute themselves in accord with fairly definite, though often complex, principles. Of the four constituents of industry, labor and capital and brains are all more easily transported generally than the crude materials upon large tonnages of which the industry must depend. Thus, cheap coal will attract manufacturers just as cheap land attracts farmers.

In studying the statistical record for the years since 1880, which

is the period of expansion and development of the mineral industry, I have been impressed with the marvelous increase both in output and in efficiency in operation. Such facts have significance as we face the future. For this third of a century just past, the growth of the mineral industry can be summed up in the statement that the value of the output has increased nearly seven-fold while our population has less than doubled. If we compare directly the output per capita of population, the record of increase in the more important mineral products becomes really instructive or even inspiring. Thus in this period of 33 years, the consumption of coal per capita has increased from less than a ton and a half to nearly 6 tons—an increase of 337 per cent. Similarly, the production of iron ore increased 357 per cent, petroleum 391 per cent, copper 1200 per cent, cement 2087 per cent; but gold and silver increased only 23 and 22 per cent respectively, while with lead the increase was 125 per cent, and zinc 638 per cent.

If statistics for the more important agricultural products are studied in a similar manner, it is found that the total increases in the same period have not much more than kept pace with the growth in population. This is true of the two leading grains, corn and wheat, the one having somewhat more than doubled, the other not quite doubled in the third of a century, so that the per capita production shows only a small percentage of increase. With cotton the gross increase has been larger, approaching 130 per cent, but wool has utterly failed to increase as rapidly as the population. It is only sugar that shows an increase, both in domestic production and consumption, at all comparable with that of the half dozen minerals mentioned, the per capita increase being 394 per cent, or about the same as the other carbon compounds, coal and petroleum.

An even more gratifying phase of this mining development is the marked increase in man's productive capacity. Let us take the 20-year period 1889-1909 and analyze the coal-mining record. Roughly stated, the number of mine-workers a little more than doubled in that period, the output of coal more than trebled, and the capital investment nearly quadrupled. The exact percentages are 123 per cent increase in employees, 226 per cent increase in production, and 252 per cent increase in capital. Stated in terms of efficiency, the mine-worker increased his individual output from 471 to 691 tons a year, while the average annual output per dollar of capital remained nearly the same, about two-fifths of a ton, the

increase in capitalization per ton of output being less than 8 per cent. Most of this increase in capital outlay was due to equipment expenditures, the improvement in mechanical equipment appreciably adding to the mine workers' efficiency and comfort.

In iron mining the record for the same period is even more striking; the number of miners increased less than one-half, the capitalization nearly trebled, and the output nearly quadrupled. In the iron mines, then, both labor and capital became more efficient, the output per miner increasing from 385 to 995 tons and the production per dollar of capital from one-seventh to one-sixth of a ton. In the case of coal mining, we know that this improvement did not halt with the census year of 1909, for since then the coal output per miner has increased another 71 tons, or more than 10 per cent in the four-year period. All this tells the story of steadily increasing efficiency of mine worker, mine equipment, and mining methods—that is, of the contribution by labor, capital, and engineering.

When I speak of the distribution of raw material, I do not, of course, shut my eyes to the influence of markets upon the location of industry. The development of transportation systems makes the problem of markets a most complex one. Cheap transportation may take away a home market from an industry or it may furnish a foreign market. The industrial independence of the small community of a century ago has given way to the system under which your dinner table may represent the tribute from several continents. Even in a country so diversified as ours in its natural bounties, domestic production of everything consumed is not desirable nor profitable. Exchange of commodities with foreign countries becomes necessary, for instance, just as soon as America can mine and smelt copper or produce and refine petroleum more cheaply than it can grow tea or raise sheep or cattle. Then the home market for cheap meat and wool and tea necessitates a foreign market for our copper and oil. Of course, the more we as a people are independent of goods sent from other countries, the less we are dependent on a foreign market for our own products. Large imports necessitate large exports, else the balance of trade will swing too far on the wrong side. Nor can we shut our eyes to the volume of exports needed to meet the interest obligations due the foreign capital invested in our railroad and industrial securities.

So it follows that in planning industrial development independence is the goal toward which a nation should face, but not a

goal which it should have either the intention or the desire to attain. As we look toward the south we find that our commerce with South America for the last four years has been one-sided to the extent of an unfavorable annual trade balance averaging more than 80 millions of dollars. The fact that the balance of trade is against the United States in two of the three "A B C" countries should be taken only as an invitation to export more. That 80 millions not only measures the present opportunity for exports to South America, but also suggests the chance for further development of trade relations. We need meat and hides from Argentina, tin ores from Bolivia, rubber and coffee from Brazil, nitrate from Chile, platinum from Colombia, cacao from Ecuador, wool from Peru and Uruguay, and coffee from Venezuela—what can we export in exchange?

To increase industrial prosperity this country needs to export finished rather than crude products and to import raw materials rather than manufactures. It is the product of American labor rather than the bounty of our natural resources that preferably should go into the world's markets. Betterment of industrial conditions can come best through expansion of manufacturing. The increase of the element of labor in the product exported will mean that we are not bartering away our heritage of natural resources but rather that we are using these resources as a basis simply for the expenditure of labor, which renews itself.

As the engineers of America study this matter of expansion of manufacturing it becomes evident that the distribution of raw material and of power is the key to industrial opportunities. So narrow, however, is the usual margin between success and failure that the practical proposition cannot be stated in terms so general. The chemical engineer requires not only qualitative but quantitative facts with which to start, and fortunately the geological engineer has come to realize this requirement. What are the mineral resources and where are they?—these are the two questions to be answered by the geologist. The answer to the "what" must be expressed in exact terms, and the value of this or that mineral to industry usually depends upon very specific factors. To illustrate: the knowledge, derived from a study of thousands of rock analyses, that the element potassium constitutes 2.49 per cent of the earth's crust possesses scientific interest and value; but as a starting point for practical work you chemical engineers would prefer a series of a dozen or two analyses of brines and bitterns from

Western marshes and Eastern wells; yet even these analyses, however accurate, would avail little except as the geologist could furnish also a quantitative statement regarding the volume represented by such samples—that is, the extent of the deposits available for utilization. And here the scientific statement of relative abundance of potassium in the earth's crust comes in to contribute to the practical work as affording a measure of probability in extent of deposits when discovered.

A source of gratification to the Government scientist, especially in the past few months, has been the fact that under new and special demands many bits of knowledge that had before been only interesting and incidental details in the scientific study of mineral resources suddenly came to possess value recognized and appreciated by the producer and consumer. The dollar mark attached itself to these facts over night.

Already readjustment of domestic industry under present conditions has resulted in the development of American substitutes for imported material. Sales of domestic manganese ores have been made to the glass trade, and production of ferromanganese on the Pacific coast is reported. The manufacture of zinc dust has followed the shutting off of the foreign supply, and barytes from the South has begun to replace the German imports. Medicinal oils derived from American crude have been placed upon the market by at least two refining companies and advertised as equal in every particular to the Russian article. Several firms have expressed their intention of manufacturing magnesium chloride from California magnesite, at least one shipment of which has been made to the East, and others are to follow via the Panama Canal. In the Western States efficient substitutes have been found for the Danish flint pebbles used in the tube mills. In California river pebbles of quartz are used, and in Idaho and Nevada pebbles are manufactured from local rock, and the reports from the mill men are to the effect that these substitutes are giving satisfaction at much lower costs.

In considering fuel and its bearing upon industrial opportunity, too much emphasis can hardly be placed upon the distribution of the world's coal. Significant facts are that 99 per cent of the world's production is mined in the northern hemisphere and that of known reserves of coal of all grades, the southern hemisphere possesses only 3½ per cent. So too, not only does the United States mine and consume 40 per cent of the world's annual output of coal,

but this country alone possesses five times as great a tonnage of unmined coal as the whole of Europe and more than 1500 times as much coal as is known to exist in South America. Do not these facts contain the promise that the manufacturing industry of this country will continue to furnish manufactures for export to Europe and South America in increasing amounts?

When we consider the distribution of coal production and coal reserves, it is noteworthy that coal is mined in 30 States and that over 16 per cent of the area of the United States, not including Alaska, is underlain by coal beds. While Pennsylvania has for a century led in coal mining and thereby possessed a proud leadership in so many industries, this State does not contain the largest reserves. The center of coal production must surely continue to move westward toward the geographic center of the nation's coal reserves, which was figured several years ago as located in southeastern Nebraska—a State, by the way, of low rank both in coal output and coal reserves.

Petroleum and natural gas in their distribution in some degree supplement coal. While the States of the Appalachian and Lima-Indiana petroleum fields are mostly coal-bearing States as well, the largest oil field, both in present production and probable reserve, is in California, a State with only negligible coal resources. Taken together, these mineral fuels constitute a national asset comparable with the coal resources of this country, but the larger part of the value of the natural gas, petroleum, and coal to the nation is in their relation to manufactures.

The wide distribution of the other items in the nation's treasury is no less notable than their abundance. Taking, for instance, the ores of the six important metals, the lack of localization can be seen in the record of last year's production by States. Listing the three leading producers for each of these six metals, we find no less than 13 States, including Alaska, in the competition. Missouri is the only State to rank first for two metals, lead and zinc. Montana stands second in both copper and silver, Colorado ranks second in gold and third in zinc, while Utah stands third in the production of three metals, copper, silver, and lead. These mining districts that are so productive of mineral wealth are scattered over the country from Alaska, ranking third in gold, to Alabama, third in iron ore, and from California, which leads in gold, to New Jersey, second in zinc. A wide distribution like this of ores sufficiently rich and extensive to

be mined in large quantities means that the metallurgical industry is important on both the Pacific and the Atlantic seaboard, and in most of the Rocky Mountain States as well as in several of the Middle States.

Even in the two metals which at once suggest centralization—copper and steel—there is widespread production. In the mining of copper last year 23 States contributed, and the mining of iron ore is not confined to any one region, even though the ranges of Minnesota and Michigan furnished 84 per cent of the tonnage and Alabama and Tennessee 8½ per cent. In all, no less than 28 States contribute iron ores to the furnaces of the country.

The diversity of the mineral industry is shown by the increase in number of products. Thus, while in 1880 the statistics of production covered 51 products, the table of production in current reports contains no less than 72 items. Furthermore, when the rapid growth of the industry is analyzed, the more marked increase is seen in that of the nonmetallic products. The old opinion that the word "mineral" carried the idea of "metallic" is overwhelmed by the relative importance of the nonmetallic mineral products. In 1880 these constituted 47 per cent of the total output and last year more than 63 per cent. Another method of stating this relative importance is that the value of the nonmetals last year was greater than that of both metals and nonmetals in any year prior to 1905.

The raw material resources of this country are so widely distributed that industry has been developing at this rapid pace at many points. I believe the tendency has been away from geographic centralization of industry rather than toward it. This State of Pennsylvania stands in a class by itself as a producer of mineral, yet its preeminence is perhaps less marked each year. Although last year its output was more than one-fourth of that of the whole country, a few years ago its share was more nearly one-third. Other factors are coming to the front each year which will create opportunities in other parts of the United States. You do not need to have these more than suggested: the South, with its happy combination of coal and iron ore in the same districts, making pig-iron production possible at minimum cost; the West, with its hydro-electric possibilities available as a source of relatively cheap power for chemical and metallurgical industries; the Rocky Mountain region, with its vast unutilized sources of sulphuric acid and equally great unmined stores of phosphate rock.

In these months of rapidly shifting currents of trade we may see even coals carried to Newcastle, but I will not presume to tell industrial chemists anything concerning the possibilities of American manufacture of coal-tar products, so essential to other industries. However, it is not apart from the present subject to mention the amount and distribution of raw material available. Of the 115 million gallons of coal tar annually produced in by-product coke ovens, more than 22 millions are available in Alabama alone, nearly as much in Pennsylvania, 16 millions in the Indiana and Illinois region, nearly half that in western New York; and Ohio, West Virginia, Maryland, Kentucky, Wisconsin, and Michigan are other important producers. Yet, so far as I am informed, few indeed are the centers where coal tar is used as a basis for chemical industry.

To return for a moment to the industrial reaction mentioned in my introductory sentence—the other ingredients necessary for producing prosperity appear at hand. A financial system already promises more mobile credits. A more sympathetic attitude of the public toward big industrial operations is indicated. The efficiency of American labor and American engineering was never questioned.

Two years ago Mr. William L. Saunders, President of the Ingersoll-Rand Company, gave his fellow mining engineers the benefit of his personal observations on manufacturing in Asia and Europe. His conclusions are of value to all engineers. He stated that manufacturing centers are not determined by abundance of cheap labor; efficient labor and the best tools are the requisites to manufacturing supremacy; the cheap labor in a Japanese steel works does not yield the low labor items on the cost sheet attained by the American manufacturers with high-priced labor; and finally the real competition with American industry is that of the efficiency of German workmen, enforced as it is by inventive engineering, rather than that of the cheapness of Asiatic labor.

In any estimate of American ability to make the most of the present opportunities for industrial expansion, you can perhaps find no better measure of the inventive genius of this country than in a moment's review of what is making the European war so terrible. Strictly neutral may we be, yet from the heights above to the depths below, we find American inventions "at the front"—the aeroplane, the magazine rifle and machine gun, the barbed wire, and the submarine and its torpedo. Cannot our nation lead as well in fashioning the tools of peace as in designing the machines of war?

DISCUSSION

Dr. S. S. SADTLER: What is the government willing to do for big business?

Dr. SMITH: That comes under several other departments than the one that I represent in a small way; but I think possibly Congress will not have time to do all that you might ask, at the next short session, which, if you figure it out, is the shortest possible session that we can have under the Constitution; as it begins just as late as it can possibly begin; and, of course, the 4th of March concludes the session. But, I think there will be less effort on the part of some of the members of Congress to restrict—to urge legislation that is of a restrictive nature. I, myself, think that Congress has already done something in the constructive way by this currency legislation to which I made reference; and I think from the reports that come to me from the various sources that the business men are realizing that when we steady down somewhat, after the shock of the European War, there is going to be more opportunity for expansion along some of these constructive lines; that there is going to be more money available for expanding the business.

I hope we will get away from any sentimental methods of helping along industry; that, as one of the technical journals puts it, that we won't follow the "Buy a bale of cotton" propaganda with a similar one for "Buy a ton of copper," but that the people with capital will take the opportunity to show their confidence; and, especially, will the better financing be shown through the new reserve bank system.

Of course, I might say, for the bureau with which I am connected, that we are doing everything that we can to bring producer and consumer together; and it is one of the most interesting types of work that I have—most interesting experiences that I have ever had. I have supposed that "Central" on any telephone system had the opportunity to "listen in" on a good many interesting conversations; but as the "Central" between the producer and consumer, I now have the privilege of reading some very interesting letters; and there are some certain needs that I had never suspected; and there are certain resources, on the other hand, that I had not suspected. The most interesting case was where a letter

requesting information happened to come just one letter ahead, on the same day, of the letter which gave the information. It didn't require very much intelligence on the part of anyone connected with the Geological Survey to make the second letter answer the first.

Dr. MARTIN H. ITTNER: I understood the speaker to say, the center of the American supply of coal is southeast of Nebraska. I should like to ask, where the center of the present *production* of coal is?

Dr. SMITH: As I remember that center was in Southern Ohio the last time we figured it. Again, we know the greatest tonnage is in this state of Pennsylvania, but the center of production is considerably west of Pennsylvania.

Dr. ITTNER: It is moving westward, is it?

Dr. SMITH: I believe it is moving westward; and I think that we did get two points on it; and they had moved westward rather faster, as I remember, than the center of population. I spoke of the total production of coal as increasing—the *per capita* production, that is altogether an increase in bituminous coal; because the anthracite curve is almost exactly parallel with the population curve, and has been for many decades.

REPORT OF THE COMMITTEE ON CHEMICAL ENGINEERING EDUCATION.

Read at the New York Meeting, December 10, 1913.

GENTLEMEN: Because of the extended labors of your former committees and the cordial discussion, by many of the Institute, of the problem you have entrusted to us, it is becoming easier to state the problem, though much still remains to be done before a proper solution can be adequately presented. The opinions brought out by earlier reports and canvasses were so varied and often apparently mutually antagonistic that it is impossible to formulate resolutions which we feel would represent the Institute. We *do* feel, however, that we are prepared, as a result of these former exchanges of opinion and experience, to present for the discussion of the Institute a statement of principles which, after modification or approval, may serve as a basis for suitable resolutions and such detailed action by your committee as shall seem of greatest service to the Chemical Engineering Profession and to educators. In addition we wish to ask the consideration by the Institute of a suggestion (still undigested) which has been proposed by a member of your committee at your committee's meeting last evening. The suggestion will give more tangible information as a basis of action on Chemical Engineering Education by the Institute than the method of securing such information which had been contemplated. The suggestion met the favor of the members of your committee present and will be given at the end of this report, but because of the absence of two of your committee the matter was voted to be presented to the directors of the Institute whose meeting immediately followed that of your committee and if no opposition to the principle appeared, the suggestion was to be presented to the Institute for action. Such presentation met the favor of the directors.

We will not, at this time, at least attempt to set up an ideal course in Chemical Engineering Education to act as a fixed stand-

ard or landmark. University and technical school courses in the best institutions are somewhat fluctuating affairs, because they are often a function of the men (teachers) in charge. A great teacher can produce results (within certain limits) irrespective of the course or arrangement. All good teachers aim at the same general educational result through the medium of the tools to which they themselves are accustomed. Nevertheless, entire freedom cannot be allowed, for the student must be made familiar with certain fields. For instance, being made proficient in water analysis or fuel analysis would never make such a student a chemical engineer though it might really be excellent training and of much help in his future engineering career.

It can very profitably, therefore, be the function of this Institute to indicate from the experience of the membership:

1. What the average chemical engineer must be and do.
2. How he must be equipped.
3. How far advanced in his development as a chemical engineer the student should be, at graduation.

The Institute recognizes and delights to honor with membership the individual who has worked his way to success in the chemical engineering profession without formal educational training. It is recognized by all, we are sure, that this process, however valuable it may be as a personal achievement, is too slow and generally fatal, for our day and generation. The industries grow too fast to wait on this slow kind of education (experience). A catalyzer is demanded which will accelerate the rate of acquiring this experience. This catalyzer we know as formal training or education. As a catalyzer without the reaction mixture is unproductive, so education will never be a substitute for experience. It is experience (practice) that makes the engineer; if he is really being made. Formal education or those in charge of it should not attempt to produce the experienced chemical engineer.

The problem which at once presents itself, therefore, is what can be done in the period of formal education that will make the experience acquired in the brief span of the professional career of the chemical engineer, of maximum value to himself and the industrial world. It is a question of the man himself and his efficiency and therefore, some one has well said, it concerns the highest form of conservation.

As the prospective engineer has been a non-productive member

of society during his incubation or education, society is interested in insuring sufficiently adequate incubation to produce as rapidly as may be, the metamorphosis from negative to positive power of production after such incubation. Although at graduation the direct drain upon educational resources parental or institutional is much or entirely curtailed, this does not necessarily transfer the account to the other side of the ledger. Since education can never replace experience as the *sine quo non* of engineering fitness, it is evident that the burden of non-productiveness is still upon society immediately following graduation although shifted to another group, i.e., from the parental or educational to the business world. An important phase, therefore, of our problem is what can be done by education to minimize the low productive stage subsequent to graduation which is subsidized by the business portion of society. In other words our recent statement of the main problem might be restated to involve the idea of the earliest practicable acquisition of reasonable and also maximum efficiency in the profession.

Fundamental Principles.

Your committee recommends the acceptance of the following statements as fundamental principles, upon which its future work should be based. We also request suggestions of suitable additional statements for consideration and decision.

I. The Chemical Engineering profession involves a knowledge of both the science and the art of chemistry as it is applied in the solution of industrial problems, the works problems of chemical manufacturing and the problems of chemical construction. Chemical Engineering is the engineering of applied chemistry as distinguished from applied analytical chemistry, or other forms of purely laboratory chemistry, whether testing or research, although it necessarily involves a more or less extended knowledge of, or touch with, these useful divisions of chemical work. Even *engineering* chemistry is merely closely allied to chemical engineering, for the chemical and physical testing of materials of construction may involve little knowledge and no ability whatever in constructive industrial chemistry or chemical engineering proper.

II. The Chemical engineer is the chemist well founded in the science of chemistry and the principles of engineering, and experienced in the handling of problems arising in the elaboration of raw materials and the design, construction or operation of machinery or

plant for the solution of the problems of manufacturing chemistry, i.e., production of useful marketable products at a profit.

III. Chemical engineering education should prepare the novice as far as can be done by education for the world of experience which awaits him in his profession, and where only, by virtue of this experience, he becomes an engineer.

IV. The graduate should preferably not enter factory work solely with academic training, but he should have had an introduction to the industrial point of view given him by some one of wide and active industrial or chemical engineering experience.

V. To properly serve the purpose intended, Chemical Engineering Education must equip the young graduate with a thorough grounding in the principles of,

1. General, physical and inorganic chemistry.
2. Analytical Chemistry (qualitative and quantitative).
3. Organic Chemistry.
4. Mathematics through calculus.
5. Physics (Mechanics, heat, electricity, light, sound).
6. English (Composition, letter writing, speaking).
7. Drawing (Machine sketching; general engineering drafting).
8. Mineralogy.
9. Mechanics of Materials (Mechanics, Strength of materials. Hydraulics).
10. Shop Work.

The major portion of a four years' course should be devoted to this foundation.

VI. The entire time need not be devoted to bare fundamentals. Therefore, the following applied subjects should be taken:

1. Mechanical Engineering (Mechanism, design, power).
2. Electrical machinery.
3. Industrial chemistry and chemical engineering.
4. Metallurgy.

VII. The following are desirable auxiliaries from the point of view of subsequent engineering practice:

1. Business law and forms.
2. German (and Spanish).
3. Research work.
4. Electro and other advanced chemistry.

These courses should be arranged where possible after suit-

ably providing for the fundamental and applied groups. Spanish is desirable for men going to the Possessions or Latin America in sugar work for instance.

VIII. The following additional subjects are desirable from the point of view of the Chemical Engineer's General education.

1. Economics.
2. Sociology.
3. History.
4. English. (Advanced composition, speaking, etc.).

IX. All the subjects listed under VI: Mechanical Engineering, Electrical Machinery, Industrial Chemistry and Chemical Engineering and Metallurgy, should preferably be omitted from the course if they cannot be taught by teachers of past and active commercial experience.

X. The teaching or attempting to teach special industries, such as paint making, paper making, and the like, should have no place in the course in chemical engineering, though doubtless perfectly proper in special trade schools.

XI. The ideal education for a chemical engineering career will involve the regular four year period plus additional post-graduate work. Nevertheless, for some time to come, if not for all time, four years will be the economic maximum for many students. The work should be arranged, therefore, so that a degree such as Bachelor of Chemical Engineering should be received at the end of the four year period, and that the man should have had by that time such training in fundamentals, that he may become a suitable candidate for works experience.

Institute Assistance.

Much assistance has been rendered to the various committees on chemical engineering education by the Institute through questionaires, papers and discussions. Considerable profit would accrue to any one interested, from reading the replies to the former questionaires, yet it must be admitted that the results as a whole were not entirely satisfactory. This is due in part to the very nature of the questionaire method of obtaining data. We have, however, no better method for ascertaining the opinion of the Institute, and desire therefore to go a little deeper into the subject by this method. We feel that another questionaire would be of little value without laying before the members a more thorough survey of the situation

than we have yet done. We therefore propose to make a detailed study of the curricula of all institutions offering courses in chemical engineering. This would be of assistance in understanding the situation as it exists in our educational institutions. Those who have ever taken the trouble to make a comparative study of the catalogues of such educational institutions will recognize at once that the results are never satisfactory. It is our opinion that if the work could be done satisfactorily, it would be of great value in bringing this whole matter to a conclusion, reflect great credit upon the Institute, and best of all, give us the satisfaction that we had done a real constructive service to Chemical Engineering Education and the profession.

We believe this can be done. The method which we propose is to send a member of the committee to inspect and report upon each and every institution, offering a Chemical Engineering course, spending a week or two at each place. This report which would be confidential for a time, at least, would be sent to the institutions concerned for comment. This would serve in itself as a powerful stimulus to those responsible at such institution. The reports and comments would be printed and sent to the membership, together with our questionaire. Then based upon all this data, and the opinions of the members of the Institute a comparative report could be prepared, which would operate powerfully upon Boards of Trustees. It would hold up the hands of those teachers who are making an honest though discouraging fight to place the chemical engineering course on a plane with mechanical and electrical engineering in the estimation of such boards of trustees who look upon this newcomer as a hybrid chemistry and mechanical engineering course, and are only too prone to consider the arguments of the man in charge of the youngster as a desire on his part to aggrandize his subject and department, and make it look big like the other engineering departments.

There are two difficulties involved in this program: First, The expense which would probably amount to $3000 or more; Second, securing a suitable man who would be willing to undergo the obvious sacrifice of leaving his professional work for a year's time for the purpose of conducting the inspection. The institute cannot finance the matter, but we believe this can be arranged by donation.

CONCLUSION.

We respectfully request therefore that before a letter ballot is taken upon the principles herein laid down and the questions which we have prepared that the Council be authorized to consider carefully the inspection proposal and reach a decision as to what procedure if any should be taken in the matter.

Respectfully submitted,

SAM P. SADTLER,
WM. M. BOOTH,
M. C. WHITAKER,
F. G. WIECHMANN,
JAMES R. WITHROW,
Chairman.

January 31, 1914.

To Members of the Committee on Chemical Engineering Education:

To the foregoing report, I simply wish to add the following:

Members of the Institute, in committee have quite fully discussed the question of a survey of the institutions offering Chemical Engineering education. Personally, I would like the members of the Institute, individually, to take this matter up. Each member would report on the institution nearest at hand in his territory. Each review should occupy at least a year.

By this method, the opinions of the members, individually, could be collected and made parts of a composite whole that would have much greater breadth than the report of one man, who could be secured for $3000. Obviously, a chemical engineer could not be obtained for this purpose, for when a man ceases to practice his profession, he ceases to become a chemical engineer.

Respectfully submitted,

WM. M. BOOTH.

February 10, 1914.

To Members of the Committee on Chemical Engineering Education:

I have signed this report because I agree in the main with the views presented by the Chairman, which were the subject of discussion also at our recent meeting in December last.

With regard to Mr. Booth's suggestion, I agree that the opinion of the members, individually, should be collected, but I doubt very much whether the reporting by different individual members upon

institutions which they might visit would be as satisfactory a plan as having some competent individual study the whole series of institutions and make a report, in detail, of their curricula; with his comments upon the same.

I think Mr. Booth's plan would lack in the unity necessary for arriving at a proper judgment, because the points of view, undoubtedly, would be distinctly different and again, an individual member of a Committee might feel a little loath to criticise an institution in his immediate neighborhood because of some local feeling which might be developed.

Respectfully submitted,

SAM P. SADTLER.

James R. Withrow (Communicated). In explanation of the point raised by Mr. Booth in his letter of January 31st, as Mr. Booth was prevented from being present at the meeting of the Society in December, it was not clear to him regarding the $3000 mentioned in the report. The report states, " There are two difficulties involved in this problem: First, the expense, which would probably amount to $3000 *or more;* Second, securing a suitable man who would be willing to undergo the obvious sacrifice of leaving his professional work for a year's time for the purpose of conducting the inspection."

It may be seen from this that $3000 is an obviously low figure, probably much too low, and was intended only to cover the clerical and other expense which such an investigation and report would involve. If it should be necessary, as would be very likely, to reimburse an individual for his time, such expenditure would increase this $3000 proportionately.

I do not believe that a chemical engineer who has stopped active practice for a purpose such as this, would necessarily cease having chemical engineering ideals.

The PRESIDENT: Gentlemen—I believe I have your consent when I extend to Dr. Withrow our very cordial thanks for his thorough report, which speaks of a great deal of labor, and I might even say love of the subject under consideration. I am impressed with the responsibilities of the Committee of which Dr. Withrow is Chairman, and the question raised by Dr. Withrow is one which is of prime importance to the Institute. It is very well to say that we must rely, for the present, at least, upon practical experience to produce the chemical engineer, nevertheless, if we view the duties of

the Institute as we ought to, we cannot help but recognize that we must take the future into consideration and we must assist in the development of the chemical engineer of the future. The best way to accomplish this, I believe is through co-operation with the schools which have courses in Chemical Engineering. Many of them do not know what the industries really require, hence it behooves us to give the schools the benefit of our experience and the benefit of our advice. Dr. Withrow has raised the very vital question as to whether the Institute should take the initiative by visiting the schools, examine their system, and submit suggestions to them and criticisms whenever necessary, as to what they should and ought to do and what they should not and ought not to do. Inasmuch as such work involves heavy expenses, I believe the question should be closely looked into by the Council. At the same time it may assist the Council in their deliberations to know the attitude of the members, and the chair will be much pleased, therefore, to hear from members on this question, which is now open for discussion.

Dr. GROSVENOR: I move that Dr. Withrow's report be accepted. It seems very clear that we should do this, and if possible carry out the recommendation of the report.

The PRESIDENT: You have heard the motion, which the chair will now put to a vote.

Motion carried.

The PRESIDENT: Dr. Withrow's committee made a suggestion that the Institute decide at this meeting whether to follow up the subject of chemical engineering education with the different Institutions of learning by investigating the courses that are now being offered at the different colleges, and then co-operate with these Institutions and correct what is lacking, add to it, or take from it, as may seem desirable.

Unfortunately, this task cannot be carried out without money, yet if the matter is taken up properly, we might find some one who will come to the assistance of the Institute.

Mr. THOMPSON: I would simply like to make a motion that we approve of the proposition of Professor Withrow if it is found to be practicable.

Dr. OLSEN: I think there is one way in which this could be carried out, or I think we could make some attempt at carrying it out without any great expense.

Our membership is pretty well scattered throughout the United

States, and we have a good many members in the vicinity of a large number of schools, and I believe that if the committee on chemical engineering education would formulate an outline of the information which they desire and correspond with members who are living in the vicinity of Institutions giving chemical engineering courses, that we could get a good many visits made by various members of the Institute, and in that way, we could get a considerable amount of information. We might not cover the whole field.

I feel myself that there is a great deal of diversity in the practice of the schools and the Carnegie foundation, which has done so much to investigate schools, has done a very great service in calling attention to places where work was deficient, and I do not see why the Institute could not do something of the same kind. We would have to do it under the guidance of the committee, and if the committee expressed clearly the information they wished, we could get a good deal in that way. I believe we could get reports on fifty institutions, if it took a year to do so, and secured members who were either in the schools or in the vicinity, and I think many members would take pleasure in visiting the institutions.

Dr. HART: This is a matter in which I am very much interested. I have been teaching chemistry for nearly forty years. Dr. F. W. Clarke in discussing educational matters of something of this source years ago, made what I thought was a very wise assertion, and that is, that we cannot lay down any hard and fast rules for any particular place, because circumstances alter cases. Our conditions are all different. They are not so different as they were in those days. There are a considerable number of institutions that have been supplied with money but that has not been my own case. It would have been very easy for me to found a chemical engineering course if plenty of money had been coming to do what I wanted, but money shortness lies at the bottom of all these difficulties. The development of the recognized courses in Institutions which are now established would necessitate the employment of additional teachers, and there the lack of money confronts us at once.

Now, it is my judgment that if this committee is going to be of real help to us, we must first try to solve one difficulty; that is, shall we have a four year course or a five year course, and I

have been trying to solve this question. I have taken it up with men like Dr. Grosvenor and Dr. Withrow. That is the first thing we ought to settle whether we should have a four year course or a five year course, and how we will bring it about; not only in the large Institutions, but also in the small Institutions, where we get many very good men. Some of the best men of the profession have come from my institution.

The PRESIDENT: I am very glad, Dr. Hart, that we can have an expression of your views this morning. Possibly, we are judging the situation too much from the viewpoint of the man who wants a chemical engineer, and not sufficiently from the viewpoint of the man who has to " make " the chemical engineer.

Fortunately, the situation is not a very pressing one. We all want to see some improvement made, but it is not a question which must be settled to-day or to-morrow, and having Dr. Withrow as Chairman of the Committee, we may feel that the committee is not going to be an inactive one, and that progress will steadily be made toward a satisfactory solution of this difficult problem.

Dr. SADTLER: As a member of the committee on Chemical Engineering education, I have been giving a good deal of thought to it. There is one difficulty in this proposed method which is brought before us.

When the agent of the Carnegie Foundation for the improvement of teaching made a canvass to standardize medical schools in this country, he cut very sharply into the question. He seemed to think that as agent of the Carnegie Foundation, he could take an absolutely independent position and bring up the standard sharply, and it made a great deal of unpleasant feeling, and it was stated at the time that the Carnegie Foundation was able to dictate as it did because they held the large funds, of which they voted the income and in that way, they were able to accomplish something. Without that, they could not accomplish anything.

We are going into a good deal of work, which will necessitate a good deal of maintenance if we have local agents report on what they think of the present condition of education in some of these schools of applied chemistry. There will be a bias on the part of individuals and it will require a great deal of careful consideration on the part of this committee before they accept unreservedly the opinions of some of these gentlemen who might have a local prejudice, and for us to take that as an established opinion and indorse

it, would make trouble for us. This idea of collecting information will have to be undertaken with a great deal of care and judgment as to what we will indorse and not indorse as to existing conditions.

Of course, we can all go ahead on the theoretical plans as to what we see in the course of chemical engineering, but in the course which they now have, we will have to use a good deal of judgment, or make a good many enemies, and I call attention to that so we will not put ourselves in an unpleasant position and a false position by taking some expressions of judgment, which if the whole thing were gone into by others, might be changed.

Mr. HEBDEN: I was very much impressed by the report of Dr. Withrow, and I think the idea as expressed in the report, when carried out by the plan as outlined, would eliminate all the bitter thoughts, which were expressed, so that there would be some uniformity, and still a good working opposition. I was very glad to note that the report to the Institute does not intend to make the engineering course a trade course. It proposes to prepare men to take up any branch. Therefore, the foundation in mathematics which Dr. Hart refers to is very essential, and the other subjects which would come along, would make the engineering course a course which could be outlined by the Institute and recommended in such a way that the whole plan could be carried out in an inventive way and have some backing thereto. I think when the committee makes its report that there will be hardly any necessity of having any further discussion on it.

Dr. WITHROW: I want to emphasize one point, and that is that I myself, consider the proposition purely as an attempt to help those, many of whom we love and hold in the highest esteem, who are making an honest effort, each in his own environment and with his own handicaps, to solve the problem of the proper training for the future chemical engineer, and not as an attempt on the part of the Institute to in any sense dictate what such faithful teachers should do. From the Institute's point of view we want to strengthen the hands of such men, and assist them by making them acquainted with our point of view for the improvement of their efforts to train young men for our particular profession.

I know that often the form of the work and often the work itself will be justly subject to criticism. I know for instance, my own work—though I am only a youth in it compared with Dr. Hart—should be subject to serious criticism. I could improve it much

myself if I could effectively get the ear and assistance of those in authority. I am not surprised therefore to find that many earnest and even well informed teachers who are endeavoring to make the most of their environment, find themselves seriously handicapped. When such men present their claims to department heads, deans, presidents, trustees, they are made to feel as though they were looked upon as the latest upstart in the general engineering field who has ambitions to aggrandize his subject and make it look as imposing as the other engineering subjects. If we could give such men an expression of the Institute's position on this matter, indicating with some authority the sentiment in the profession, it would enable them to go to their Boards of Trustees with the weight of authority behind them, and we would have strengthened their hands. On the other hand, such an investigation and report as proposed would stimulate all to better work, and doubtless beneficially arrest the attention of some who may be without adequate idea of the proper point of view.

I feel that if the plan can be made practicable it is desirable. On the financial side it may be possible to interest the Carnegie Foundation for the Advancement of Teaching. They are said to be about to go into the Engineering field, and if they find us so interested they may go into the Chemical Engineering side with us. The most difficult side of the matter in my opinion is the securing of a proper sympathetic individual of experience in this kind of education for the inspection. In this connection I am convinced that it must be done by one man, or if more than one they must go together, for all must be seen with the same eyes for adequare comparison and in order that justice be done. Such a program will be time consuming, and will involve much sacrifice on the part of the individual, divorced in this way for a time from his professional work.

Mr. CHUTE: It seems to me that we might go so far as to authorize the Council to approve of certain courses, or rather the courses at certain Universities, but before they did that, they should, of course, make inquiries where possible, also suggestions and criticisms, all of which would, of course, be approved by the Council, and the withholding of the approval of the Council from any University or any course would merely indicate that they had not sufficiently examined it yet, but we might where we find a course

that we approve, at least authorize the Council to publicly approve such a course.

The PRESIDENT: Is that an amendment to the motion before the meeting? Mr. Thompson made a motion that the Council should investigate whether the suggestions contained in Dr. Withrow's report are practicable.

Mr. THOMPSON: That is do we approve of the plan,—whether it is practicable, and do we approve of the general plan as reported by the Committee on Chemical Engineering Education?

The PRESIDENT: I think we all recognize the broad constructive idea underlying Dr. Withrow's suggestion, and if there is no further discussion, we shall act on the motion of Mr. Thompson, which has been seconded.

Motion put and carried.

THE PRESENT STATUS OF THE CHEMICAL ENGINEERING EDUCATION WORK, OF THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS.

By JAMES R. WITHROW (Chairman)*

The meeting of the Committee on Chemical Engineering Education held December 9, 1913, at the Chemists' Club, New York City, voted to lay before the Directors of the Institute certain suggestions regarding a first hand investigation by the Institute of the present status of chemical engineering courses in our Universities and Technical Schools. These were referred by the Directors to the Institute, and a motion was passed at the business session of the New York meeting of the Institute that the Committee be instructed to proceed with the investigation of the present status of chemical engineering education in our universities and technical schools, provided, in the opinion of the directors, the financing of the work could be adequately taken care of without interfering in any way with the financial standing of the Institute. It was suggested at that time to get in touch with the Carnegie Foundation for the Advancement of Teaching to ascertain if the Foundation would be interested in co-operating with the movement which we had in mind.

Subsequent to that meeting President Whitaker appointed a new committee to continue this work, and while awaiting instructions from the President, your chairman proceeded to get in touch by correspondence with the Carnegie Foundation, seeking information as to whether a rumor that they were contemplating an investigation of the teaching of engineering had good foundation and to ascertain the purpose and scope of this proposed investigation. A reply to this inquiry was received from President Pritchett of the Carnegie Foundation as follows: "In co-operation with a committee appointed by the different engineering societies the Carnegie Foundation has undertaken to make an examination of the curriculum of courses of study now in use in American Universities and Engineering schools. For this work Professor Mann of the University of

* Presented verbally at the Troy Meeting.

Chicago has been chosen, but he will not undertake the active part of it until the autumn, when he will come to the Foundation and spend a year in the preparation of this study. I shall be very glad of any co-operation with you in the matter.' Your chairman immediately replied that the American Institute of Chemical Engineers would be glad to co-operate with the Carnegie Foundation to the utmost of its power and informed the Carnegie Foundation that we have been interested since the foundation of our Institute in carefully studying the conditions surrounding chemical engineering education and the practical requirements which it should meet, with the idea of being of as much assistance as possible to those who are attempting to make chemical engineering students as proficient as possible at the time of graduation. Further information regarding the co-operation which President Pritchett mentioned as under way with the committee appointed by the different engineering societies was requested, and also information as to with whom this movement originated so that we could get our bearings and determine what the attitude of our Institute should be in this connection. This letter was written early in April and to it no reply was received.

About this time your chairman discovered that the Society for the Promotion of Engineering Education had a joint committee on engineering education working in conjunction with representatives from several engineering societies. Inquiry was therefore made at once to the secretary of the Society for the Promotion of Engineering Education, Prof. H. H. Norris, Ithaca, N. Y., as to the scope and meaning of this joint committee and calling attention to the fact that our Institution had been actively at work on this question for the last five years or more. A prompt reply was received from Prof. Norris stating that their committee had been in existence a number of years and that it had not presented as yet any definite report, but they were now working with the Carnegie Foundation for the Advancement of Teaching, which he said was to take up a study of technical education and that a preliminary report from their committee was expected at the Princeton meeting of the Society for the Promotion of Engineering Education in June, 1914, and continued as follows: "I doubt if it would be worth your while to take the matter up yet with the Committee or the Foundation for the reason that preliminary plans have not yet been formulated. On May 16th there will be a meeting in New York at the office of the Foundation, after which we are hoping for more definite news."

Your chairman was referred by Prof. Norris to a member of the faculty of Ohio State University for a history of the movement.

At this time your chairman not having as yet any real information to communicate to the Committee merely informed the President of our Institute, and one or two of the members of the committee with whom he had occasion to correspond, of the unsatisfactory status of the information we were seeking. Your chairman proceeded to investigate the records of the Society for the Promotion of Engineering Education to ascertain, in the absence of other definite information, just what the history of the movement in that Society had been. It was found in the Proceedings of the Society for the Promotion of Engineering Education, 1907, page 17, that the President, Prof. Dougald C. Jackson, presented a set of resolutions inviting the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, and the American Chemical Society to appoint two members each to form a committee with three members from the Society for the Promotion of Engineering Education, which joint committee was charged with the duty of examining into all branches of engineering education, including engineering research, graduate professional courses, undergraduate engineering instruction, of the proper relation of engineering schools to the secondary industrial schools and foremen's schools, and to formulate a report or reports upon the appropriate scope of engineering education and the degree of co-operation or unity that may advantageously be arranged between the various engineering schools; that the said joint committee should be requested to make a report of progress to this Society within one year and a final report within two years. In the same Proceedings, June 24, 1908, page 47, the preliminary report of this committee was read by D. C. Jackson, giving a biographical sketch of the members and suggesting ways of carrying on the work of the committee. No meeting of the committee had been held and at the request of the committee the following resolutions carried: (p. 2)

"WHEREAS, The time consumed in the formation and organization of the Joint Committee on Engineering Education has been greater than was expected, and,

WHEREAS, The work of this committee can be greatly facilitated by co-operation with the Carnegie Foundation for the Advancement of Teaching, and with the General Education Board, be it

RESOLVED, That the date for presentation of the final report of the Joint Committee be coincident with that for holding the regular annual meeting of this Society in 1910, and be it further

RESOLVED, That the action of said committee in extending an invitation of membership to the President of the Carnegie Foundation for the Advancement of Teaching and to the General Education Board be and hereby is approved. Also

RESOLVED, That the joint committee be authorized to print its preliminary report at once, if, in its judgment, so doing will advance the interest of its work."

The next year, 1909, page 3, an informal report was mentioned as being presented (report or remarks not in the Proceedings) and a more complete report was promised for the following year. Since then there has been no report, though the Secretary, Volume XIX, 1911, page 13, was instructed to ascertain the status of the Joint Committee.

Your chairman decided at the beginning of June as he had failed to receive any reply to his request for information directed to the Carnegie Foundation in the middle of April, that he would visit the offices of the Carnegie Foundation in New York and see if the information desired for presentation to this committee could be secured by personal inquiry. He therefore visited New York and notified the Foundation that he would be in New York between certain dates and requested an interview. This elicited a prompt reply from the secretary of the Foundation, Dr. Clyde Furst, who said that Dr. Pritchett was out of the city but would be glad to see your chairman at any time between the 10th and 13th of June before he left for California and said in addition that "plans for our study of engineering education are now being formulated, after a number of conferences with the Joint Committee on Engineering Education, by Prof. Mann of the University of Chicago, who will begin active work on the first of September."

Your chairman, therefore, visited the offices of the Carnegie Foundation on the first date set by the secretary thereof and was accorded a very cordial interview with President Pritchett of the Foundation who expressed regret that in the course of his absence from the city there had been such delay in reply to our committee's letter of April 14th. President Pritchett was asked regarding the purpose and scope of the investigation to be initiated by the Foundation. He stated that their object was to investigate the present

status of engineering education in universities and technical schools with the idea of formulating, with the co-operation of these schools, desirable ideals which such engineering education should continuously hold before itself for the mutual good of engineering and the general public.

Regarding the scope of the investigation the Foundation was to decide as yet. They were doubtful as to whether they should include mining engineering and chemical engineering. It is believed by your chairman that the free and full discussion of the subject at this and subsequent interviews was appreciated by the officers of the Foundation and that the Foundation Officials now appear more favorable to the inclusion of chemical engineering education within the scope of their investigation.

An extended discussion by your chairman of various phases of the question was permitted by President Pritchett and the history of the movement in our Institute was laid before him as well as our object, the results which we have obtained so far, and the project for the securing of more exact information which we have in mind at the present time. It was pointed out that the Institute could assist chemical engineering education as a censor of the product by sitting back and accepting or rejecting candidates for admission to the Institute when they appeared, but it preferred to assist educators in the more helpful way it has been attempting, for the last few years, through its committees on Chemical Engineering Education. It was made evident that the Institute has been actively working on this question and that much has been accomplished. The value of this work was attributed to the fact that the committees of the Institute on Education have been mainly composed of practical men. Your present committee for instance, consisting of two men active in commercial work solely and three who have been or are active teachers. All of these latter are actively engaged in commercial or consulting work, one being the head of an important commercial consulting laboratory and another president of an important chemical manufacturing company.

Through the kindness and at the suggestion of Secretary Olsen of our Institute your chairman was enabled to lay before President Pritchett and leave with him the bound Volume IV of the Transactions of our Institute and all of the bulletins which we have issued which take up the subject of chemical engineering education and which will place before the Foundation and its investigators the

whole inside workings of our investigation, so that they may see as clearly as we see, the progress which we have made and the many unsatisfactory conditions regarding our investigations which we appreciate still exist. This frank exposure of our detailed results should give much assistance to any future investigators. It seemed to your chairman that the Foundation felt that little had been or would likely be accomplished by the education committees of other societies and it was stated that they were anxious to throw their burden on the Foundation. Your chairman suggested that such an arrangement would also be acceptable to the American Institute of Chemical Engineers as far as the expense was concerned. It was pointed out, however, that in any event our Institute meant to continue its work and prosecute it to the end it had in mind in the laying before educators and authorities of the Universities and Technical Schools the point of view of the Institute after we had adequately canvassed the situation. It was pointed out that in the event, for instance, of a report from the Foundation being in discord with our experience we would feel bound to criticise their position and give publicity to our own. President Pritchett cordially assured your chairman that such public discussion was exactly in accord with the Foundation's wishes not only because of the good which such discussion would entail, but because it would give the Foundation opportunity to recede from any false position taken by it possibly as a result, for instance, of inadequate association with the problem. This indicated a spirit in the Foundation which should be much appreciated and which will stand, if maintained, as a strong offset to any possible accusation of being arbitrary in its recommendations or findings. With regard to the question as to whether our Institute could be of assistance in the matter, it was suggested by President Pritchett that while the Foundation could vote no money, yet the Carnegie Corporation might be induced to financially aid our movement, but more practical still, President Pritchett suggested that if the Institute would be willing to act as the agent of the Carnegie Foundation, the Carnegie Foundation could bear in all probability a large portion of the expenses of such co-operative investigation.

President Pritchett requested your chairman to return the next day to meet Prof. Mann, who happened to be on his way from Chicago. Your chairman returned and spent an hour or two in conversation with Prof. Mann, who is a professor of physics in the

University of Chicago and who has apparently been giving the matter of the projected Foundation investigation considerable attention. He has apparently had considerable experience in the collection of data on phases of education and is therefore not new at this kind of work. He expressed considerable interest in chemical engineering education and it was a pleasure, as a result of the extended work of our various committees to be able to give Prof. Mann, at his request, what we believe to be a clear and concise definition of what chemical engineering is, and what chemical engineering education should be, as defined and outlined in our report submitted to the Institute December, 1913. Mr. Mann expressed pleasure at the clearness of our definitions and the work which we had done and expressed a desire to confer with your committee or members thereof during the course of his investigation next year.

President Pritchett requested that your chairman write him the latter part of October for an appointment to meet Prof. Mann and go into more details in these matters if the Carnegie Foundation at that time desired further information. In the course of conversation with officers of the Foundation it was intimated to your chairman that the Carnegie Foundation after all was the proper authority to conduct these investigations as they were conducting them, and that in our case as in others their decision would involve a certain amount of finality. Your chairman was glad to agree that the work which the Foundation is doing as far as he was able to tell is of great benefit to education in general. He nevertheless felt constrained to emphasize the fact that however painstaking the investigation of the Carnegie Foundation might be, it would not necessarily give to the investigation of our branch of engineering as much weight as recommendations from our Institute, since an Institute such as ours which consists of men who are practical leaders in this profession would be listened to by educators in preference to others, be they ever so able, for these men constituting our Institute are representative of the men who are to employ the graduates and who see most clearly the defects which exist in the product of our technical schools. At any rate the opinion of such a body of men as ours will always be carefully considered by those who wish to assure themselves that their earnest efforts in educating young chemical engineers are being directed from the best point of view. This attitude was finally conceded to have much weight.

It was a pleasure to note that there was emphatic agreement with the Institute by the Carnegie Foundation that not money, but rather the man conducting the investigation was the important factor, and they thoroughly believe, as we do, in having the whole investigation done by one man rather than by different isolated individuals, though it is probable that a group of two or three men travelling and working together would be better than one alone. President Pritchett expressed the opinion that he would desire our representation on the joint committee of the Engineering societies which are working with him in this matter. Your chairman offered as far as in his power the official assurance that our committee and the Institute itself would do anything in its power that would contribute to the good of engineering education, and particularly chemical engineering education.

These interviews were held so recently (latter part of last week) that the results have not been communicated to all the members of your committee, but are presented here at the request of the President and Secretary of the Institute. After the interviews an attempt was made to hold a meeting of the committee during these Troy sessions, but it was evident that this eleventh hour notice was inadequate, particularly in view of business engagements of most of the members. The committee, however, will probably agree to the suggestion of President Whitaker to your chairman that your committee temporarily suspend further operations and await the formulation and development of the Carnegie Foundation's investigations.

TROY, N. Y., JUNE 25, 1914.

REPORT OF THE COMMITTEE ON CHEMICAL ENGINEERING EDUCATION.

Presented at the Philadelphia Meeting, December 2, 1914.

Dr. WITHROW: The committee presents an informal report; because the present status of the committee work is "watchful waiting," which is so common nowadays. The committee during the past year was able to get in touch—active touch—with the Carnegie Foundation for the Advancement of Teaching; and an informal statement was made at the Troy, N. Y., meeting, of progress made in that direction. According to correspondence with Secretary Olsen, that statement has been reduced to formal writing and will be printed together with this meeting's report of progress in Bulletin form, and will be in your hands. I will not take the trouble, therefore, to read the formal Troy report to you again, as it is rather lengthy; but the gist of it is, the Carnegie Foundation is rather interested in the work which our Institute has carried out, and have promised to seriously consider taking up chemical engineering education. President Pritchett of the Carnegie Foundation stated to me in New York that they were going into the investigation of the teaching of engineering in the Universities and technical schools in this country, but were not decided whether they would, or would not, go into mining engineering and chemical engineering. What the result will be, therefore, is problematical. I have not heard from them decisively, although I have written to feel them out, two or three times recently, but have received no satisfaction.

We agreed at the Troy meeting that we should wait and postpone our activities, as far as the committee was concerned, until we found out definitely what the Carnegie Foundation's attitude would be. When I saw Dr. Pritchett in New York in June, they hadn't as yet decided on their own program. They expected to do that during September and October of this year; and, as stated, I have received no reply from them as to what they propose to do.

The committee, therefore, this morning has simply to report progress of a somewhat stationary kind.

We have, however, a matter of importance to this committee to lay before you. We have not had time to confer with Secretary Olsen since our committee meeting this morning, but understand that

it was agreed at a former meeting, for good and sufficient reasons, to omit the printing of committee reports in our bound volume of transactions. Your committee therefore requests that as far as the Committee on Chemical Engineering Education is concerned that this program be rescinded, and that the committee's reports on education be printed in the bound volume of the transactions. Our reasons for this are as follows: They are now printed in the bulletin form; but those bulletins are thrown, probably, into the waste-basket by librarians; and our Institute, as an organization, is represented by a bound volume, only, which stands on the shelves. Now, there are other organizations which are interested in engineering education, also; and they have printed very little along the lines in which we worked, because they have done very little; but we recently stated in one of our Education Committee reports, that past committees—not this one, but past committees—have done considerable work; and we therefore request the Institute that the past work, not yet printed in the Transactions, be printed in the next bound volume. That, as far as I am personally familiar, begins with the committee report of last year. This is the request which we make, this morning, of the Institute.

The CHAIRMAN: You have heard the Report of the Committee on Education; what is your pleasure?

(Motion made that it be accepted and placed on file.)

The CHAIRMAN: Moved that the report of the committee be accepted and placed on file. Any discussion?

Mr. MCKENNA: About this participation of the Carnegie Foundation in our work, I utter a warning that we should think deeply as to the meaning of such a co-operation, as to what it might commit us to in the future. We want to go gently into the participation, or into the giving up of our own duties. I hardly understand just what you have proposed, and I don't know what it means in the future; but I have in mind some criticisms of the Foundation which really have been well founded; but we could perceive, couldn't we, that if the sole project of our educational methods as a profession were left with them, it might be handled and discussed in a weak and unsatisfactory manner; and that the independence in our Institute and this Committee on Education might be jeopardized—we should preserve that independence. I am speaking rather wide of the mark; but I don't understand what the Carnegie Foundation would intend to do with the subject we have before us, or what our commit-

tee has actually suggested that we could do with that foundation. But I only throw out the warning that we should not lose our independence.

I make this motion: to have the committee's report accepted and placed on file; and I have another motion after that.

The CHAIRMAN: Any further discussion?

Dr. WITHROW: I believe the point made by Dr. McKenna is well taken, and we should seriously bear it in mind. I will just read one paragraph from the Troy report (which will bear directly upon that point), which is in the report itself and will be printed in connection with this meeting.

I emphasized with them that irrespective of any report which they might make, we would reserve to ourselves the right to criticise it. President Pritchett was kind enough to say, that was exactly what they would like to have us do, because, for instance, it could easily be possible that their investigation would be in error, and that our criticism would give them the opportunity to recede if they were in error, as might well be, because they didn't have the close association that we might have with the problem. He apparently recognized that situation; and I thought his point of view was at least charitable—and a very commendable one. Our attitude was very well received, I think. It was clearly recognized that we have not committed ourselves to anything at all, though we will assist them as far as in our power lies. They don't know, yet, what they want to do, as a matter of fact; but it was made clear to them, that we—our Institute, would be perfectly independent, irrespective of what they might do.

The CHAIRMAN: Does that answer your question, Dr. McKenna?

Dr. MCKENNA: Yes.

The CHAIRMAN: It was my understanding that it was the desire on our part to make the Foundation shoulder the expense (which they could easily do) of standardizing Chemical Engineering Education—of particularly studying the courses of chemical engineering offered in the different institutions and prepare their own report, so that we could get some pretty definite material on which to work. It was felt originally, that we should carry out such a thing as that, and it was found that it would cost three or four thousand dollars—to send a man around and get the information on the spot. It was afterward thought that we could get it very largely done by the Carnegie Foundation.

THE NEED OF REVISED CHEMICAL STATISTICS

By BERNHARD C. HESSE

Read at the Philadelphia Meeting, December 4, 1914

The information imparted by statistics is of two kinds: the first deals with domestic production and the second with international exchange of commodities.

The difficulty at the outset is a definition of or a rule for such things as should appear in chemical statistics. Endless discussion could be had on that topic. The classification in Schedule A of our Tariff is one way of settling the question; the classification in our Census Reports is another way, but what of those products on the Free List in our Tariff that are undoubtedly of interest to chemists and to chemical industries, and what of those other products and industries contained in our Census Reports dealing with industries other than those therein classed as chemical?

The classification adopted by the Germans as shown in reports in, for example, the "Chemiker Zeitung" at page 169 for 1914 and in the previous volumes of that publication, is still another way of settling the matter.

The classification contained in the Monthly Summary of the Foreign Commerce of the United States as published by the Department of Commerce is still another way of handling this material. In all there have been here brought out four modes of handling this material.

Those who compile all our statistics are confronted with the responsibility of completing their task and they have, no doubt, done it very well and in the light of the very best information they can get. If there be any shortcomings affecting us in those statistics we can surely look to ourselves as the cause, in that we have not taken proper steps to designate the kinds of materials which we consider necessary for our commercial and industrial information. Also, in making any requests for changes in those statistics, we must be prepared to give heed to the desires and the requirements of others.

It is probably true that none of our present methods of handling our statistics comes so near to satisfying the needs of American chemists and chemical manufacturers as would a treatment like that adopted by the Germans and just referred to, and yet even that classification would not fully meet our requirements.

Our international statistics, in order more nearly to be of substantial service to the chemical interests of this country, need revision, but just what that revision shall be I am perfectly frank to confess that I do not know. Neither do I believe that any other *one* man knows, but I believe that we all agree that they do not fulfill the purpose.

That being the case, the question first to be considered is the remedy. I suggest that the American Institute of Chemical Engineers take the initiative and with the co-operation of all other chemical organizations in the United States ascertain what articles should be specifically enumerated in our import and export statistics; all organizations and trade publications should be invited to participate, and care should be taken that every possible interest, both geographical and industrial, is provided for in such an attempt to get the sense of the chemical industry of this country. As a first approximation of such articles, it might be well to take up those that are specifically enumerated in the Tariff and then to take up those that are enumerated by class or sub-class therein. Care will have to be exercised that on the one hand the classification is not too minutely divided so as to make the work burdensome to the Federal Government and without real clarity to those who use the results so compiled and on the other hand, that the classification be not so broad that the user cannot tell with reasonable accuracy what articles are really included in such classifications. No doubt, the German classification will be an excellent guide, but in making the final list the statistical data of other countries, such as Great Britain, France and Austria should be consulted.

The advantage to be gained by such segregation would be to bring to the attention of domestic chemical manufacturers new domestic needs of chemicals provided for from foreign sources, long before such foreign sources have become successfully intrenched in the business in this country. Such things things have happened and they may happen again and the way to prevent their recurrence is something of the kind just suggested.

While it is true that many of our trade publications have pub-

lished in each issue such information, yet it has not been classified and has not been arranged so that it is easy of inspection and it would be asking altogether too much to expect our publications to do it; they publish the news and the individual should dig out his own information.

However, the Federal Government with its large equipment can more easily tabulate and classify that material and thereafter print and distribute it better, quicker and cheaper than any other available agency. It is not to be expected that this additional labor should be performed by the Federal Government without recompense and probably a moderate subscription fee would be sufficient to cover this added expense and, no doubt, there will be enough subscribers to such special compilation to make it useful and not a source of serious loss to the Government.

The compilation of import and export statistics is a large task and changes in it should not be undertaken without thorough consideration. Before requesting any such changes we ourselves should undergo every reasonable labor to ascertain what will better answer our requirements, carefully examine those suggestions and test and re-test them to see that we have made no error and then submit them to those in charge of the statistical work. Suggestions made in that way and with that thoroughness will, no doubt, receive corresponding serious consideration; without some such serious, thoughtful and well-planned suggestion it is not to be expected that the Federal Government will change its present mode of handling the matter.

What has been said of import and export statistics is true of our production statistics, that is, our Census Reports, and any changes that we may have to suggest in them should be just as thoroughly and thoughtfully prepared, tested and examined as those in the export and import division.

The need of a change is apparent; just what that change shall be requires the most thoroughgoing co-operation of as many chemists and chemical manufacturers in this country as can possibly be made to co-operate; the initiation of a work of such magnitude is not to be taken up lightly but should be carefully weighed and studied and if positive action be decided upon, all who partake in it must be prepared to sacrifice much time, much thought and much labor.

90 WILLIAM STREET, NEW YORK CITY.

DISCUSSION.

The CHAIRMAN: Dr. Hesse has obviously brought forward in his paper a subject of great importance to this Institute. There is every reason why our membership should take the most active interest in his suggestions. We all have occasion to use statistics and unless they are complete and up-to-date they are of little value. Much of the statistical matter now available from government sources is of the vintage of 1909. Conditions have changed materially since that date and the information is obviously useless. As Dr. Hesse suggests, the government bureaus will doubtless be ready and anxious to co-operate with us provided we tell them what we want.

The SECRETARY: It seems to me that Dr. Hesse's suggestion is so obviously a good one, that I doubt if we need very much discussion. I believe we have all pretty well agreed that co-operation between the technical societies and the government in this respect is to the advantage of both sides; and I believe the Federal Government and its officials will welcome co-operation on the part of a body such as the American Institute of Chemical Engineers.

I wish to move, Mr. President, that a committee of three be appointed to take up this matter of statistics, as suggested in this paper; and they communicate with the proper authorities for such action as they may deem fit. I think the committee ought to be given rather broad powers and present the matter again if they deem it necessary.

Dr. SAMUEL P. SADTLER: The motion ought to be amended to the effect that this committee ought to be a committee to co-operate with similar committees from other organizations. When the motion was made, it struck me at once that if we were merely to handle this thing and report back to this Institute, that would not accomplish at all what Dr. Hesse wanted.

The SECRETARY: I will include the suggestion that the committee be authorized to co-operate with similar committees from other societies in this work.

Mr. FITZHUGH LEE: I suggest that we might solicit other societies to co-operate with us; as we happened to see it first.

The SECRETARY: I think there is one point in this connection that we ought to consider. There are some of our societies who act slowly, and others who act quickly. I think that our committee ought to be instructed to get busy right away. If the other societies want to get busy, all right; but our committee, I think, ought to go ahead and get all the co-operation possible, but in the meantime carry on this propaganda.

The CHAIRMAN: If there is no further discussion, the motion in its amended form is substantially as follows: that the Institute appoint a committee to co-operate with, and collaborate with the other chemical societies in formulating and submitting to the government bureau a plan for the compilation and distribution of up-to-date statistics.

Carried.

The President-elect Rosengarten will have the appointment of this committee.

THE APPLICATION OF PHYSICAL CHEMISTRY TO INDUSTRIAL PROCESSES

By WALTER F. RITTMAN

Read at the Troy Meeting, June 17, 1914

The luxury of to-day is the necessity of to-morrow; likewise the theory of to-day is the practice of to-morrow. Gayley's process of drying air for a steel furnace, the various nitrogen-from-air processes, the contact process of manufacturing sulfuric acid, synthetic indigo, synthetic tanning materials—all were in the field of abstract theory but a few years ago. To-day they are practical realities. Similarly, many of the theoretical principles and processes of to-day will, in all probability, be realities a few years hence.

The invasion of chemistry by physics, and the production of what is known as physical chemistry, promises to be a most important basis for progress in the field of applied chemistry. Whereas physical chemistry is often looked upon as one of our most theoretical subjects, it will be found to be one of our most practical as well. Its principles are useful regardless of the materials involved in the reactions, whether copper, steel, soap, glass, cement, gas, textile, or any other chemical product. Physical chemistry is described as that branch of chemistry which has for its object the study of the laws governing chemical phenomena. When these laws and their application to a reaction or process are once understood, it is a relatively easy matter to select the most favorable physical conditions. The task of the chemical engineer is to produce these most favorable working conditions in an apparatus which operates on an industrial scale. A further advantage of a knowledge of theoretical principles and perhaps one to be more frequently applied is the aid such knowledge gives in avoiding fantastic so-called improvements.

The chemical engineer rarely creates new products; he deals with processes and machinery which produce quantities economically. Obviously his problems often differ from those of the laboratory

chemist. The fact that a reaction is slightly exothermic or endothermic is of secondary consequence in laboratory experiments, but in applied engineering this fact at once determines whether the reaction should be carried out in a cooled or in a heated apparatus. The amount of heat given off in a reaction, such as the hydrogenation of a vegetable oil, is of no serious consequence in laboratory experiments, but where tons are handled the accumulated heat is sufficient to ruin any process which does not provide for its disposal. Latent heat of fusion or of evaporation is not important in the laboratory where there is always an excess of heat or cold, but in many cases this heat of fusion or of evaporation becomes all important in its influence on the cost of an industrial operation. The cost of the heat absorbed by an endothermic reaction seldom concerns the laboratory chemist; but it is profit or loss to the chemical engineer. The percentage of yield, and the cost per unit, are the vital questions to the engineer; they are usually not vital to the laboratory chemist, however valuable and constructive his work may be.

It sometimes seems as if the inertia of years has limited the temperature imagination of many engineers and some chemists. Theoretical considerations might suggest the broad field which comprises the several thousand available degrees above the boiling-point, as well as the 273 degrees below the freezing-point of water. Likewise, we are prone to overlook the great advantages which sometimes may be derived from the application of pressures greater or less than the one atmosphere which surrounds us and with which we are so familiar.

Because of the numerous possibilities in the application of physical chemistry to industrial processes, I must greatly restrict myself in dealing with the subject. Some of the most interesting parts deal with equilibrium relationships, phase-rule applications, radioactivity, energy considerations and electrolytic reactions. Excellent examples illustrating the successful application of each can be found, but to-day I shall deal in some detail only with the one mentioned first, i. e., equilibrium relationships.

I shall not attempt to deal with every branch of modern production which involves the equilibrium relations of physical chemistry, nor shall I attempt to advance speculations as to future applications of equilibrium relations in industry. The attempt will be confined to successful present-day applications, by way of examples. However familiar these processes may be, I hope that there will be at

least something interesting, if not new, in pointing out that these familiar processes have a purely theoretical aspect. In fact, dealing with them historically indicates that they have all developed out of the most abstract theoretical reasoning into the practical machinery of economical production.

Oxidation of Nitrogen from Air—It is known that at room temperature there is no perceptible union of the nitrogen and oxygen of air; it is known that at temperatures as high as 3000° C. only a partial union takes place; it is known that the amount which does unite is a function of the temperature; that is, at each temperature there is a definite percentage of nitric oxide formed, and equilibrium exists between the combined and uncombined constituents. In other words, the tendency of the uncombined constituents to combine at any particular temperature is exactly counterbalanced by the tendency of the combined constituents to separate at that temperature. There is a true equilibrium. Experiment has proven that when air analyzing 79.1 per cent N_2 and 20.9 per cent O_2 is brought to equilibrium at 2400° C. the resultant mixture analyzes 2.23 per cent NO, 77.98 per cent N_2 and 19.78 per cent O_2,[1] i. e., 1.116 per cent of an atmosphere each of nitrogen and oxygen have disappeared in the formation of nitric oxide. Further, let it be clear that this 2.23 per cent of NO obtained at 2400° C. is not an accidental figure; it will always be the same when air of the above composition is brought to equilibrium at 2400° C. This fact makes it possible to calculate the equilibrium constant for nitrogen, oxygen and nitric oxide at 2400° C.

$$N_2 + O_2 \rightleftarrows 2NO - 43200 \text{ cal.}$$

$$K_{2400^\circ \text{ C.}} = \frac{p^2_{NO}}{p_{N_2} p_{O_2}} = \frac{(0.0223)^2}{(0.7798)(0.1978)} = 0.0032,$$

where p represents the partial pressures of each of the three constituents; i.e., the part of the whole pressure exerted by each. The constant K which joins these partial pressures has a definite numerical value for each definite temperature. The square of the partial pressure of NO, divided by the product of the partial pressure of N_2 multiplied by the partial pressure of O_2 for any mixture of these three constituents in equilibrium at 2400° C. will be equal to 0.0032. Through the application of thermodynamic principles,[2] it

[1] Nernst-Finckh, *Z. anorg. Chem.*, 1905, p. 116; ibid., 1906, pp. 212, 229.

[2] Nernst, "Theoretical Chemistry," 7th German edition, pp. 575–6; Morgan, "Elements of Physical Chemistry," 5th edition in press.

is possible to calculate the value of K' for any other temperature from the above experimentally determined value of K for 2400° C. From this value of K' for any other temperature, as 3000° C., for example, it becomes a simple matter to calculate the yield of NO which will be obtained from any initial mixture of nitrogen and oxygen brought to equilibrium at that temperature. Percentages of N_2, O_2, and NO which satisfy the equilibrium relationship for any temperature will always be obtained when these constituents are brought to equilibrium at that temperature. Further, the reaction is reversible, and reaches the same results from either direction. A number of values for equilibrium constants of this reaction at different temperatures have been calculated. From these values the percentage yield of NO from air has been calculated, and the calculations have been checked, as follows:[1]

TABLE I

COMPARISON OF CALCULATED AND OBSERVED VALUES OF EQUILIBRIUM CONSTANTS FOR THE $N_2+O_2 \leftrightarrows 2NO$ REACTION

Temperature Deg. C.	NO (Calculated from values of K) Per cent.	NO (Observed) Per cent.
1538	0.35	0.37
1604	0.43	0.42
1760	0.67	0.64
1922	0.98	0.97
2307	2.02	2.05
2402	2.35	2.23
3060	5.00	

It is observed that until 3000° C. is exceeded the yield of NO is below 5 per cent. The above clearly indicates how theoretical considerations show the limits of a reaction as well as the most favorable conditions for its industrial application. The oxidation-of-nitrogen process obviously is limited in practical application to localities where large quantities of cheap electric power are available.

Contact Process of Manufacturing Sulfuric Acid—The contact process of manufacturing sulfuric acid, considered from the equilibrium viewpoint, can be expressed by the equations:

[1] Nernst, *Z. anorg. Chem.*, 1906, pp. 213–228; *Z. f. Elektroch.*, 1906, pp. 257, 529; Jellinek, *Z. anorg. Chem.*, 1906, pp. 229–276; Nernst-Finckh, *Z. anorg. Chem.*, 1905, p. 116.

$$SO_2 + \tfrac{1}{2}O_2 \rightleftarrows SO_3 + 22600 \text{ cal.}$$

$$K = \frac{p_{SO_3}}{p_{SO_2} p_{O_2}^{1/2}}.$$

A few values of K follows:[1]

TABLE II

CONSTANTS FOR CONTACT PROCESS OF MANUFACTURING SULFURIC ACID

Temperature Deg. C.	Kp (experimental)	
400	580	(calculated
450	188	
515	65.4	
600	14.9	
800	1.81	
900	0.57	

Upon calculating the maximum yields of SO_3 obtainable at the different temperatures from the various values of K, it is observed that the yield rapidly decreases as the temperature increases. This is in contrast to the nitric oxide illustration where the yield of NO from N_2 and O_2 increases with the temperature. As the temperature increases in the $SO_2 + O_2$ reaction the values of the equilibrium constants decrease rapidly. At the temperatures below 400° C., however, the union of SO_2 and O_2 is too slow for an industrial process. At this temperature there is but a slight sacrifice of the percentage of SO_2 and O_2 combination.

Temperature, however, is not the only thing which influences a reaction of this nature. Without entering into a mathematical discussion of the influence of pressure we can recall LeChatelier's principle: that pressure stimulates those reactions involving contraction, while vacuum encourages those reactions involving expansion.

Further, temperature and pressure do not complete the factors influencing chemical reactions where equilibriums are involved. The third and important factor is the relative concentration of the various reacting elements. The SO_3 reaction furnishes an excellent example showing the influence of the concentration of the combining reagents.

[1] Knietsch, *Ber.*, 1901, p. 4069; Bodländer u, Koppen, *Z. f. Elektrochem.*, 1903, p. 787; Bodenstein u. Pohl, ibid., 1905, p. 373.

Observing the mathematical expression for the equilibrium relationship,

$$K = \frac{p_{SO_3}}{p_{SO_2}\, p_{O_2}^{1/2}} \quad \text{or} \quad \frac{p_{SO_3}}{p_{SO_2}} = K\sqrt{p_{O_2}},$$

it becomes evident that the relative yield of SO_3, with respect to SO_2, increases as the partial pressure of oxygen increases, since the value of K for any given temperature does not change. This can best be observed by giving K the arbitrary value 200, and assigning to O_2 the partial pressures 0.25, 0.50, 1.00 and 2.00: Then

$$\frac{SO_3}{SO_2} = 200\sqrt{\text{partial pressure } O_2},$$

and the ratios desired are given below:

TABLE III

EFFECT OF CHANGING THE CONCENTRATION OF ONE OF THE CONSTITUENTS IN AN EQUILIBRIUM

Partial Pressure of Oxygen.	Ratio of SO_3 to SO_2.
0.25	100
0.50	141
1.00	200
2.00	282

This influence of an excess of oxygen is of practical value and is used in the commercial manufacture of SO_3.

Synthesis of Ammonia from Hydrogen and Nitrogen—Another illustration of the factors entering into chemical equilibriums involving temperature, pressure and concentration is the Haber method of manufacturing ammonia from nitrogen and hydrogen.[1] The synthesis of ammonia from nitrogen and hydrogen depends upon the equilibrium represented by the expression,

$$\underbrace{\tfrac{1}{2}N_2 + \tfrac{3}{2}H_2}_{2 \text{ volumes}} \rightleftarrows \underbrace{NH_3}_{1 \text{ volume}} + 1300 \text{ cal.}$$

$$K = \frac{p_{NH_3}}{p_{N_2}^{1/2}\, p_{H_2}^{3/2}}.$$

A few investigated values for K follow:[2]

[1] *Zeitsch. f. Elek.*, 1913, p. 53.

[2] F. Haber, "Thermodynamics of Technical Gas Reactions."

TABLE IV

EQUILIBRIUM CONSTANTS FOR THE AMMONIA SYNTHESIS

Temperature Deg. C.	*K* (experimental).	*K* (calculated).
700	.....	0.00068
800	0.00033	0.00036
1000	0.000148	0.000145

Haber[1] found that as the temperature rises above 500° C., the yield of NH_3 is low, while below 500° C., the rate of reaction is too slow. He eventually so perfected his experimental apparatus that his yields of NH_3 permitted him to calculate K from experimental data and compare the same with theoretical values. The close correspondence of the theoretical and actual values indicates how experiment reinforced by theory will often show what can be expected in practice better than imperfect experimental results without theory. Without theory, in fact, Haber would never have known whether his experimental work was perfect, imperfect or worthless.

In this ammonia reaction, equilibrium relations are such that when the reaction is practiced under atmospheric pressure the maximum yield is not sufficient to warrant industrial application. A yield of less than one-quarter of one per cent is of little more than scientific interest. Through the introduction of increased pressures, however, the contraction from two volumes to one volume is greatly favored and the process yielding twelve per cent at once becomes of decided commercial interest. In the oxidation-of-nitrogen process, on the other hand, there is no change in the number of volumes, and pressure is without influence on the reaction. This pressure influence in connection with equilibrium relations is strikingly shown in Table IV.

TABLE V

PERCENTAGE OF NH_3 IN THE EQUILIBRIUM OF THE REACTION

$$N_2 + 3H_2 \rightleftarrows 2NH_3$$

Pressure in Atm.	Temperature Deg. C.				
	550	650	750	850	950
1	0.0769	0.0321	0.0159	0.0089	0.0055
100	6.70	3.02	1.54	0.874	0.542
200	11.9	5.71	2.99	1.68	1.07

[1] F. Haber, *Journal of Industrial and Engineering Chemistry*, 6 (1914), 325.

Other Applications of Equilibrium Relations—The equilibrium relationship between reacting agents persists throughout all chemical phenomena. The relative amount of CO_2 to CO issuing from a furnace is primarily a function of temperature and pressure, and is influenced by the machine only in so far as the machine influences these variables. The equilibrium between CO_2 and CO in the presence of carbon for any temperature is reached regardless of whether one starts with CO or with CO_2, or with any mixture of the two.

$$CO_2 + C \rightleftarrows 2CO,$$

$$K = \frac{p^2_{CO}}{p_{CO_2}}.$$

TABLE VI[1]

EQUILIBRIUM RELATIONS BETWEEN CO AND CO_2 IN PRESENCE OF CARBON

Temperature Deg. C.	Per Cent by Volume.	
	CO	CO_2
450	2	98
750	76	24
1050	99.6	0.4

Typical examples of this relationship are found in the kitchen stove, the factory boiler, the blast furnace, the gas machine or the open-hearth furnace. Doubling the size of the blast furnace changes the relative amounts of CO_2 and CO only so far as doubling the size of the furnace influences the temperature in the various reacting zones. With increasing temperature the percentage of CO increases, with decreasing temperature the percentage of CO_2 increases. In the blast furnace, for instance, not only are the CO and CO_2 in equilibrium, but the various oxides of iron are likewise in equilibrium with carbon, CO and CO_2, as well as with one another. Consider the blast-furnace reactions:

$$2CO \rightleftarrows C + CO_2$$
$$Fe_2O_3 + CO \rightleftarrows Fe_3O_4 + CO_2$$
$$Fe_3O_4 + CO \rightleftarrows 3FeO + CO_2$$
$$FeO + CO \rightleftarrows Fe + CO_2$$

[1] J. Mellor, "Modern Inorganic Chemistry," p. 713.

from the equilibrium point of view; there is found to be a vital relationship between them. On first sight a series of equations of such a nature looks very complex, but on the application of equilibrium relationships, formulated by means of the phase-rule diagram, it is found to be relatively simple and clear. Experimental work[1] has been done on these relationships, from which it is possible to plot the diagram of equilibriums.

All of the reactions are reversible, their direction is entirely a function of temperature. From the diagram, the fields of stability

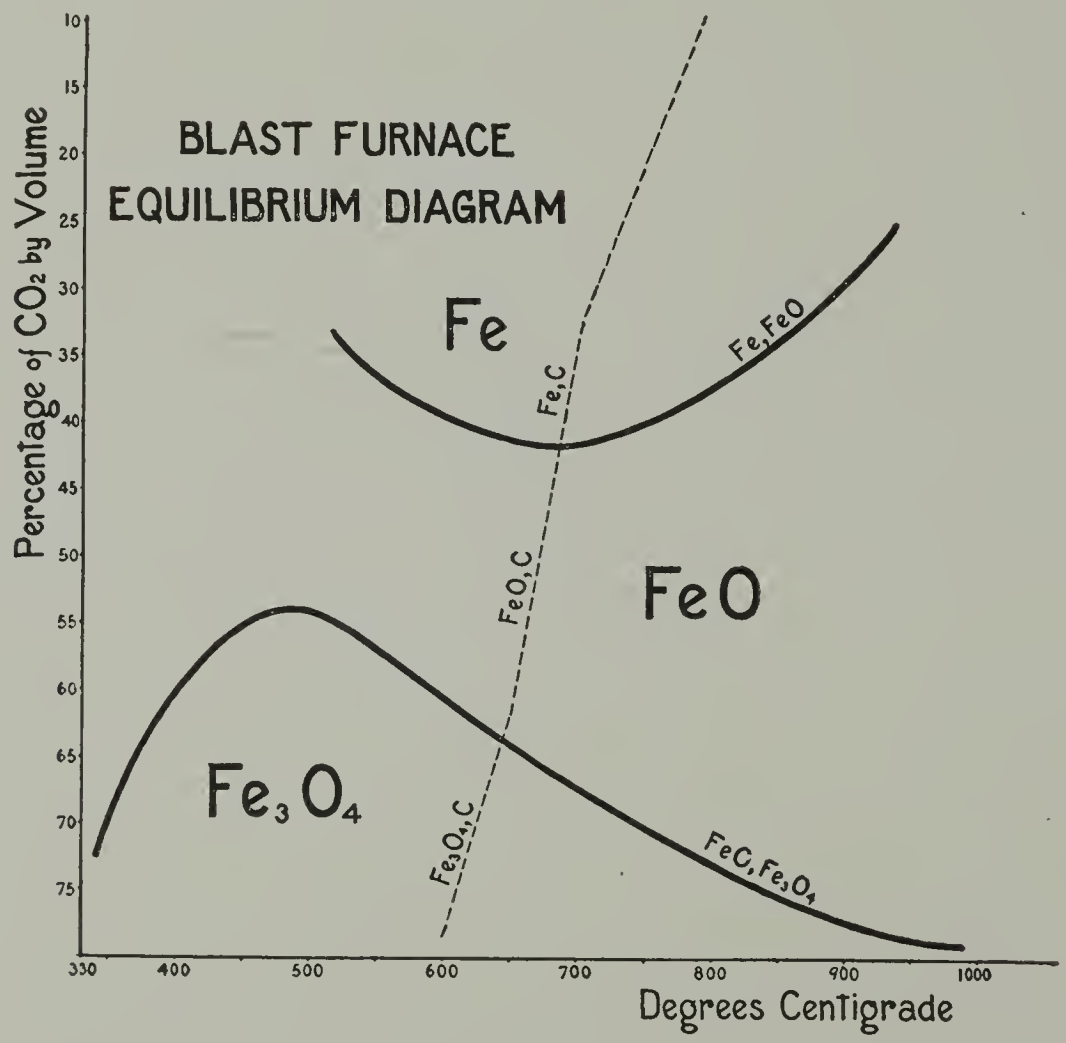

FIG. 1.—Blast Furnace Equilibrium Diagram, Showing Relations between C, CO, CO_2, Fe, FeO, and Fe_3O_4.

of Fe, FeO and Fe_3O_4 in the presence of CO and CO_2 for the temperatures shown can be observed. It can be noted, for example, that FeO at 650° C. is not stable in the presence of more than 65 per cent or less than 43 per cent CO_2. It becomes evident that in the reduction of FeO to Fe a maximum of CO_2 in the flue gases is obtained when the reaction takes place at about 675° C., and that this percentage of CO_2 decreases as the temperature increases. The

[1] Baur und Glaessner, *Z. physik. Chem.*, 1903, p. 354.

diagram indicates that most of the reduction takes place in the cooler part of the furnace.

Coefficient of Partition or Distribution—Equilibrium conditions also prevail in the more purely physical world as well as in chemistry. A solute which divides itself between two immiscible solvents will always be found in a definite concentration in both solvents, and there will always be a definite ratio between the concentration in each. This ratio is known as the partition or distribution coefficient. I will cite first the laboratory example dealing with iodine, water and carbon disulfide. Iodine is slightly soluble in water and much more soluble in carbon disulfide, while water and carbon disulfide are practically insoluble in each other. Suppose we have both water and carbon disulfide in one vessel and add some iodine. It has been observed from experiments that the concentration of iodine in the carbon disulfide is 588 times the concentration of iodine in water. In other words,

$$K_{\text{Iodine}} = \frac{C_{CS_2}}{C_{H_2O}} = 588.$$

In similar manner, iodine divides itself between ether and water so that the concentration of iodine in the ether is 200 times the concentration of iodine in the water.

$$K_{\text{Iodine}} = \frac{C_{\text{ether}}}{C_{\text{water}}} = 200.$$

Similar examples can be found in the distribution of acetic acid between benzene and water, benzoic acid in benzene and water, succinic acid in ether and water, acetic acid in chloroform and water, saccharin in ether and water, acetanilid in ether and water, vanillin in ether and water, or acetanilid in chloroform and water. This aspect of equilibrium is finding application in analytical chemistry, more especially in that branch dealing with alkaloids.[1] Through its application the haphazard washing-out process in alkaloid work is replaced by one of mathematical precision. Technical application can be found in Parke's process for extracting silver from lead. Silver is very much more soluble in zinc than in lead, whereas lead and zinc are only slightly soluble in each other. The lead containing silver is melted and thoroughly mixed with a

[1] J. W. Marden, *Journal of Industrial and Engineering Chemistry*, 6 (1914) 315.

small proportion of zinc. The zinc floats to the top, carrying with it in solution practically all of the silver, and on cooling solidifies while the lead is still molten. The zinc containing the silver is then skimmed off, and these two constituents separated.

Lack of time forbids the consideration of the equilibrium relationships existing in the ionization of acids, bases and salts. Their application in analytical chemical methods is to-day a reality; their technical application promises much.

EQUILIBRIUM RELATIONS ARE OF GENERAL APPLICATION—The equilibrium or kinetic relationship is accepted and used by theoretical chemists, and is believed to prevail in practically all fields of chemistry. When considered in mathematical units it changes qualitative suggestion into quantitative information. Equilibriums deal with yields in terms of percentages or weights, they deal with temperature, pressure and concentration in numerical terms. When so applied, they are concrete and cease to be more theoretical than any other mathematical statement.

Equilibriums exist between reacting agents in solution; between reacting liquids; between liquids and vapors; solids and liquids; solids and gases; between gases which react chemically; between the concentrations of a solute divided between two immiscible solvents; in the ionization of acids, bases and salts, in hydrolysis and saponification; in fact in all the chemical and physical phenomena with which the chemist or the chemical engineer deals. The industrial development and application of physical chemistry, including this equilibrium principle, is only partially realized to-day; its further deveopment and application seem to depend largely upon competition and necessity, and the stimulus they offer to the inventive faculties of chemical engineers as the leading specialists in this most promising field of our science.

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THE USE OF HYDROMETALLURGICAL APPARATUS IN CHEMICAL ENGINEERING

By JOHN V. N. DORR

Read at the Philadelphia Meeting, December 4, 1914

This paper, although the title is somewhat general, will be devoted principally to a description of the apparatus with which my name is connected. It was prepared at the suggestion of President Whitaker, who felt that it would interest chemical engineers to know of methods which have proved of definite value in metallurgical work where large quantities of material are handled with low costs.

General Metallurgical Tendencies. Metallurgical engineering is really one department of chemical engineering in its broadest sense. Comparing metallurgical operations of to-day with the work of thirty years ago, we note that nearly everything is done on a much larger scale. One reason for this is the general development of engineering knowledge with improved materials and the substitution of exact scientific methods for the old " rule of thumb " ways. Another is the greatly increased demand for metallurgical products, the consumption of all the common metals having increased several times as fast as the growth of our population. A third and perhaps more important reason is that most of the smaller rich ore deposits have been worked out so that we have been forced to attack the large low-grade deposits which twenty years ago were considered of no value.

This tendency is well shown by the treatment of the disseminated porphyry copper ores and the handling on a much larger scale of the lower grade ores at Butte and in the Lake Superior district. The introduction of mechanical power in place of hand labor has, of course, been as important a factor in metallurgical progress as in all other lines of endeavor.

The introduction of continuous methods in the different steps of metallurgical processes in place of intermittent methods formerly used, has lead to great advances. Continuous work invariably means lower labor costs and a high load factor, thus assisting in

lower power costs and interest charges. Where the change does not sacrifice control of the operation it results usually in allowing a large output of uniform nature.

As illustrations of this tendency towards continuous work in metallurgy may be noted the use of pan conveyors and rotary cylinder feeders in delivering ore to primary crushers, automatic weighing machines, and belt conveyors for the transport of dry material around a mill. The belt conveyor is also in use for stacking tailings from leaching tanks and has been used to stack slime tails from an Oliver filter and dewatered sand tails from a Dorr Classifier. In smelting plants we see the use of mechanical roasters and sintering machines, such as the Dwight-Lloyd, with continuous removal of slag by granulation.

The change in cyanide practice has been quite marked. Where leaching was practiced the original means of removing slime was to collect the sand in tanks while overflowing the slime, and then shovel or otherwise transfer the sand so collected to other vats for leaching. Continuous separation whether by cones or mechanical classifiers has done away with this, and the sand usually passes directly to leaching tanks without coming to rest.

In slime treatment, whether of classified slime or the whole mill feed reground, Dorr Continuous Thickeners have made continuous settling feasible and continuous agitation has replaced the charge system for the dissolution of precious metals, with a very definite saving in power, attention and first cost of the installation required. The Oliver Continuous Filter has come into extensive use for that step in the process. It is interesting to note that the decantation process, the first method used for the recovery of dissolved gold from slimes, which was abandoned everywhere except in South Africa on the introduction of the modern type of filter, when made continuous by the use of the Dorr Thickener, is coming into extensive use again and displacing in some instances intermittent types of filters.

Zinc-dust precipitation, when first introduced as an intermittent process, could make no headway against continuous precipitation with zinc shavings, but since being made a continuous process by Merrill has come into extensive use in modern mills.

Interchange of Apparatus in Industries. One characteristic of technological work in the last few years that was not in evidence in the centuries preceding is the exchange of information

among workers in different fields. Although the total knowledge in the world has increased so enormously, and this has been called very properly an age of specialization, the specialist is expected to have a general knowledge of progress outside his own field to such an extent that he can profit by it in advancing his own work. This has been made easier in metallurgy than in most other industries, I should say, by the greater freedom that exists among metallurgists in the exchange of data. A valid reason for this is that the metallurgist competes in a much greater degree with natural conditions than with other producers of the same product.

The price of gold is essentially constant whether more or fewer mines are operating and, while the prices of silver and the base metals vary with the supply and demand, the profits may depend so greatly on other factors, such as richness of the ore and costs of mining and milling, that I doubt if any producer would hope to get an advantage over the other by secrecy. In fact, there is a general understanding among the larger copper companies to-day for an exchange of information which gives them all an advantage in the combat with Dame Nature.

In manufacturing, on the other hand, there is competition for the purchase of the raw material and the sale of the finished product so that manufacturing costs and profits must come between the two, and any advance that can be made in reducing the former seems of no real benefit unless kept from competitors.

The cyanide process has been advanced by the adoption of methods and machinery from other industries and has made its own contribution in return. Fine grinding has been aided materially by the adoption of the tube mill from cement grinding, and when dry crushing and chlorination on Cripple Creek ores was in vogue the inclined traveling screens used in clay working were of great assistance, as were the dust collectors taken from Minneapolis flour mills. Our early paddle-arm agitators came from chemical works and the air-lift agitator or " Pachuca " tank which succeeded, was first used, I am told, in a powder plant in California.

The plate and frame filter press so extensively used in Australian metallurgical practice was another adoption from chemical industries, and the rotary drum filter was used as a dewaterer of chemical precipitates before the cyanide process was known. As developed by Oliver with means for washing and blowing

off the cake formed, it has been returned by the cyanide operator to several industrial uses.

Various forms of vacuum and pressure "cake" filters such as the Moore, Butters, Kelly and Sweetland, might be said to have their prototype in the potters' method of making pitchers, which is done by pouring "slip" into a plaster of Paris mould and when a solid deposit has been formed by the absorption of moisture, pouring out the remainder of the liquid "slip" and drying the vessel thus formed in the mould. From cyaniding they have found their way extensively into sugar refining, alkali works and many other lines. The Merrill Sluicing Press is being installed in a large aluminum plant in the South.

In closing this general discussion I will say that, while the basic principles for the mechanical treatment of analogous materials are the same, great caution should be used in proposing the substitution of any method or apparatus successful in some other field for that now used. It is safe to assume that the latter is in use as a result of much study and gradual development, and its replacement should be preceded by a most careful detailed study of all the conditions of operation and the purposes to be accomplished. Suggestions as to such substitutions may be advanced tentatively, but an actual demonstration is worth a lot of theorizing. In introducing new methods we usually find troubles come where not expected, and apparent difficulties do not prove real.

THE DORR APPARATUS—GENERAL

The apparatus which I wish to call to your attention was developed by me in the last ten years in the course of operating cyanide mills in the West. Each machine performs a certain useful function satisfactorily and economically and I feel that you will agree with me that where similar work is to be done they are worthy of consideration. I do not mean, of course, that a machine adapted for handling a sandy pulp is necessarily the best type to handle an extremely light chemical precipitate, but I feel that, where the operations of washing, settling, or agitation are required, they may be of service.

As a generalization, I believe I am safe in saying that machinery successful in operations where costs per *ton* are studied to a fraction of a cent, have possibilities where materials are handled on

which cost per *pound* are watched. It is true, on the other hand, that the economies of continuous work decrease with a reduction of tonnage, so that each case has to be studied by itself. In discussing the apparatus I have of necessity quoted freely from my paper on the same read at the Salt Lake Meeting of American Institute of Mining Engineers in August, 1914.

THE DORR CLASSIFIER

This machine was devised by me in 1904 to replace hydraulic cones for the purpose of making a separation of sand and slime

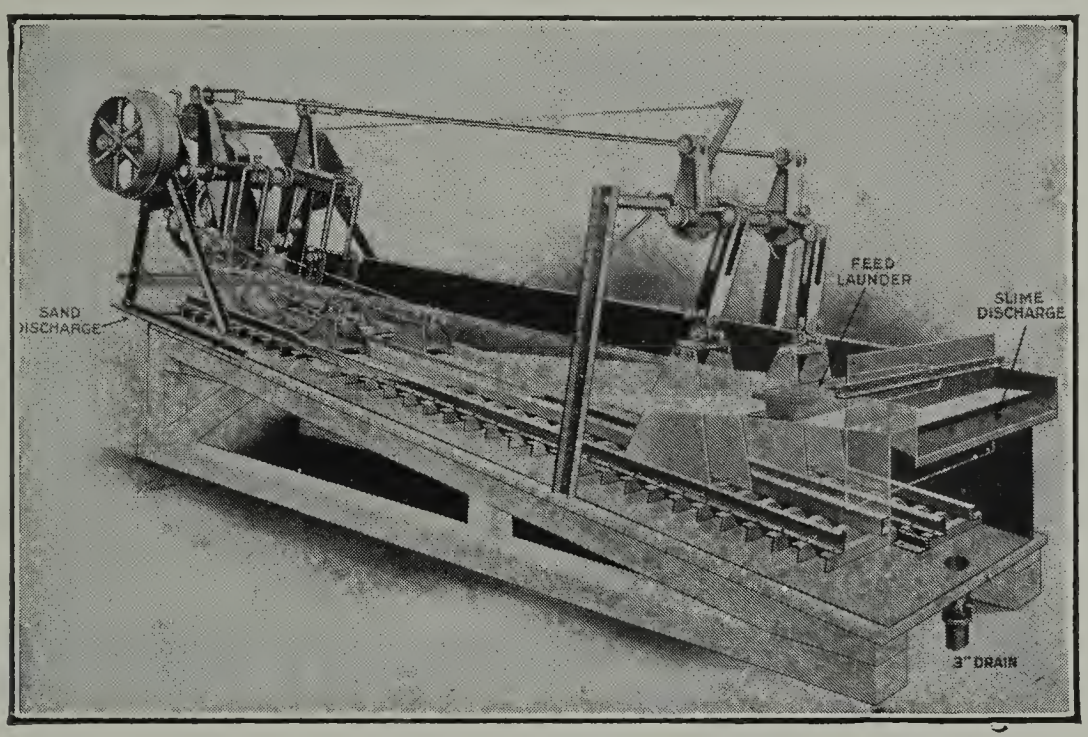


FIG. 1.—The Dorr Classifier (Patented), Model "C."

at the mill of Lundberg, Dorr & Wilson, at Terry, South Dakota. The method of cyaniding the gold ore in use at that mill was crushing to pass a 20-mesh screen, separating the sand from the slime, leaching the sand in vats by percolation and treating the slime after agitation and thickening by the Moore filter process. The machine proved such an improvement over the cones in use at our plant and elsewhere that it was rapidly adopted and has come into wide use. It has been improved from time to time to meet new conditions and as now manufactured is shown in Fig. 1, which illustrates the standard duplex machine.

The Dorr Classifier consists of a settling box, in the form of an inclined trough with the upper end open, in which are placed

mechanically operated rakes or scrapers for the purpose of removing the quick-settling material from the open end, the liquid and slime overflowing at the closed end. Each rake is carried by two hangers; one at the sand-discharge end suspended from an arm attachment to a rocker arm or lever, which terminates in a roller; the other depends from a bell crank connected by a rod to the same rocker. The roller is kept pressed against a cam on the crank shaft by the weight of the rakes.

The rakes are lifted and lowered at opposite ends of the stroke by the action of the cams transmitted through the rocker arms and bell cranks, and the horizontal motion is obtained directly from the crank.

The bell cranks at the slime end are carried by a second larger bell crank held in position by a chain attached to a spool on a worm gear at the head end of the Classifier. By this means the rakes can be raised 10 inches at the lower end and operated in that position or any intermediate one. This allows the Classifier to be started readily when nearly filled with sand after an unexpected shutdown, and the regulation of the depth of the settling box when in operation to vary the products being made.

The pulp is fed across the settling box as shown and a uniform flow to the lip at the end is maintained while the sand settles to the bottom and is advanced by the rakes until it emerges from the liquid and is discharged with from 20 to 30 per cent moisture. The agitation near the bottom of the tank, caused by the reciprocating motion of the rakes, assist in keeping the slime in suspension, but is not normally sufficient to cause fine sand to overflow.

Regulation of Products

The machine is intended, of course, to make only two products, and the point of separation can be varied by the following means:

1. The use of the baffle shown, which allows a reduction of the cross-section of flow so as to overflow more fine sand.

2. Raising the rakes and thus obtaining the effect of operating them in a shallower tank.

3. Increasing the speed of the rakes until the agitation keeps fine sand in suspension.

4. The attachment of perforated spray pipes to the rakes at a point where they remove the sand from the liquid, allowing a

rewashing of the sand and removal of any slime that may be carried down with it.

This latter feature will probably be of more interest from the chemical engineers' standpoint as enabling him to discharge finely divided sandy material and give it a complete wash to free it from any dissolved material which adheres to it.

Capacity

The capacity of the Dorr Classifier depends upon the dilution of the feed and the point of separation which it is desired to make. The rakes of the standard duplex machine, operating at normal speed, are able to discharge at least 150 tons of solids in twenty-four hours.

The following table below showing results at different plants will give the best idea of what may be expected. The results given were obtained with the standard duplex Classifier, but both larger and smaller sizes of machines are to be had.

OPERATING DATA ON DORR CLASSIFIERS

Mill.	Tons per 24 Hr.	Feed.				Sand.			Slime.		
		Dilution.	+100	+200	−200	+100	+200	−200	+100	+200	−200
Portland, Colorado..	145*	5 to 1	38.3	13.4	47.1	75.3	16.2	7.4	0.9	5.8	94.7
Golden Cycle, Colo..	151*	3.5 to 1	45.0	19.0	36.0	68.0	23.0	9.0	...	11.0	89.0
Cia Benef. de Pachuca, Mexico.....	144†	4 to 1	42.7	25.1	32.5	43.6	40.1	16.8	0.1	3.8	96.8
Tonopah Exten., Nev.	73‡	6 to 1	65.0	11.1	23.9	70.0	18.3	11.7	0.6	8.5	90.9
Amparo Mining Co., Mexico.....	125*	7.5 to 1	52.4	18.5	29.1	71.4	27.4	1.2	...	6.5	93.5
Tonopah-Liberty, Nevada.....	85‡	7 to 1	30.5	41.9	26.3	75.7	24.0	0.1	2.5	14.3	81.4
Goldfield Consolid., Nevada.....	264§†	3 to 1	40.0	12.0	48.0	74.0	19.0	7.0	2.6	19.5	79.1
Tonopah-Belmont, Nevada.....	70‡	.....	65.6	2.7	28.9	...	...	...	0.4	6.6	93.0
Alaska-Treadwell, Alaska‖.....	89‡	.....	48.7	41.5	9.8	48.7	41.5	9.8	...	2.0‖	98.0
Nipissing, Canada...	...	.....	78.7	3.6	16.8	85.8	7.2	6.9	...	0.5	99.5¶

* New ore.

† Includes tube-mill return. Under normal conditions, with a tube mill in closed circuit with a Dorr classifier, 35 to 50 per cent of original feed returned.

‡ New ore; tube-mill product returned, but amount not stated.

§ 168 tons come from the stamps, the rest being returned from the tube mill.

‖ Classifiers used in connection with the regrinding of concentrates; rakes operated 24 strokes per minute; 100 per cent of concentrates pass 200 mesh; the 2 per cent is silica from tube-mill pebbles.

¶ Of this 200-mesh product 15 to 20 per cent is sand; crushing is done in two sets of tube mills; the sand from the first classifiers being reground is closed circuit with tube mills and other classifiers, the combined slime overflows, giving the screen test shown.

Since the above was written Simplex Classifiers are being successfully used to make a separation at 60 mesh, operating in closed circuit with Hardinge mills, showing a capacity including return of 500 tons of solids per 24 hours.

Special Classifiers, 6-foot wide, have also been built and are successfully making a separation at 48 mesh, handling 1200 tons of solids per day including return.

Cost of Operation

Experience has shown that repair costs on these machines are extremely small. I know of one Classifier which operated nearly four years with repair costs of less than $5.00, and half a mill per ton seems a safe figure. While the power taken will vary of course with the load, it appears that $\frac{1}{4}$ H.P. is ample in most cases. With normal feed the attendance required is practically nothing, being limited only to an occasional oiling. All parts in reciprocal motion are removed from contact with the liquid so that there is no opportunity for wear starting at any point.

Uses

Besides being used to separate a leachable sand product from slime, Dorr Classifiers are in general used to-day in connection with fine grinding.

Fig. 2 shows the arrangement of Dorr Classifiers and tube mills operating in closed circuit in the Tonopah-Belmont Mill. It is considered much more economical in power and equipment when a product perhaps 150-mesh or finer is desired, to pass a large tonnage continually through a tube mill, return the discharge to a Dorr Classifier and overflow the part which is ground fine enough, returning the balance to the same machines for further grinding together with the sand coming from the new feed. This is considered much more efficient than to attempt to reduce the product to the size required in one passage through the tube mill. It seems more than probable that it will prove equally advantageous in connection with industrial pulverization of quartz, flint, barytes, cement material and other mineral products that require fine grinding. Some work has already been done on these lines, especially in connection with pigment grinding, but I have no data that are at present available.

Dorr Classifiers are now in successful use as dewaterers of con-

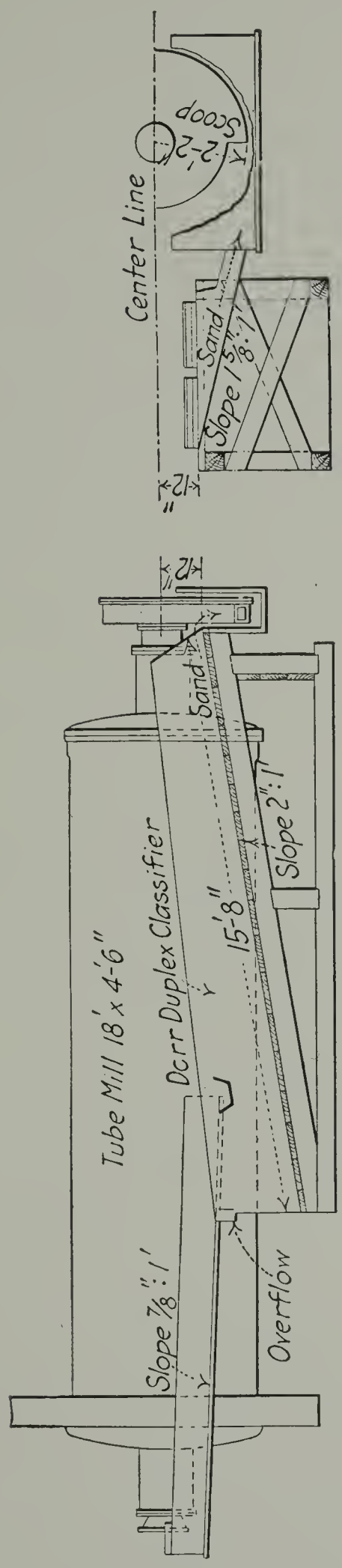


FIG. 2.—Arrangement of Classifiers and Tube Mills Operating in Closed Circuit in the Tonapah-Belmont Mill.

centrates, both magnetic iron concentrates and sulphides, and are discharging the former at one plant with only 12 per cent moisture.

Leaching

The use of a series of Dorr Classifiers for the purpose of leaching and washing was first suggested by Mr. Utley Wedge and

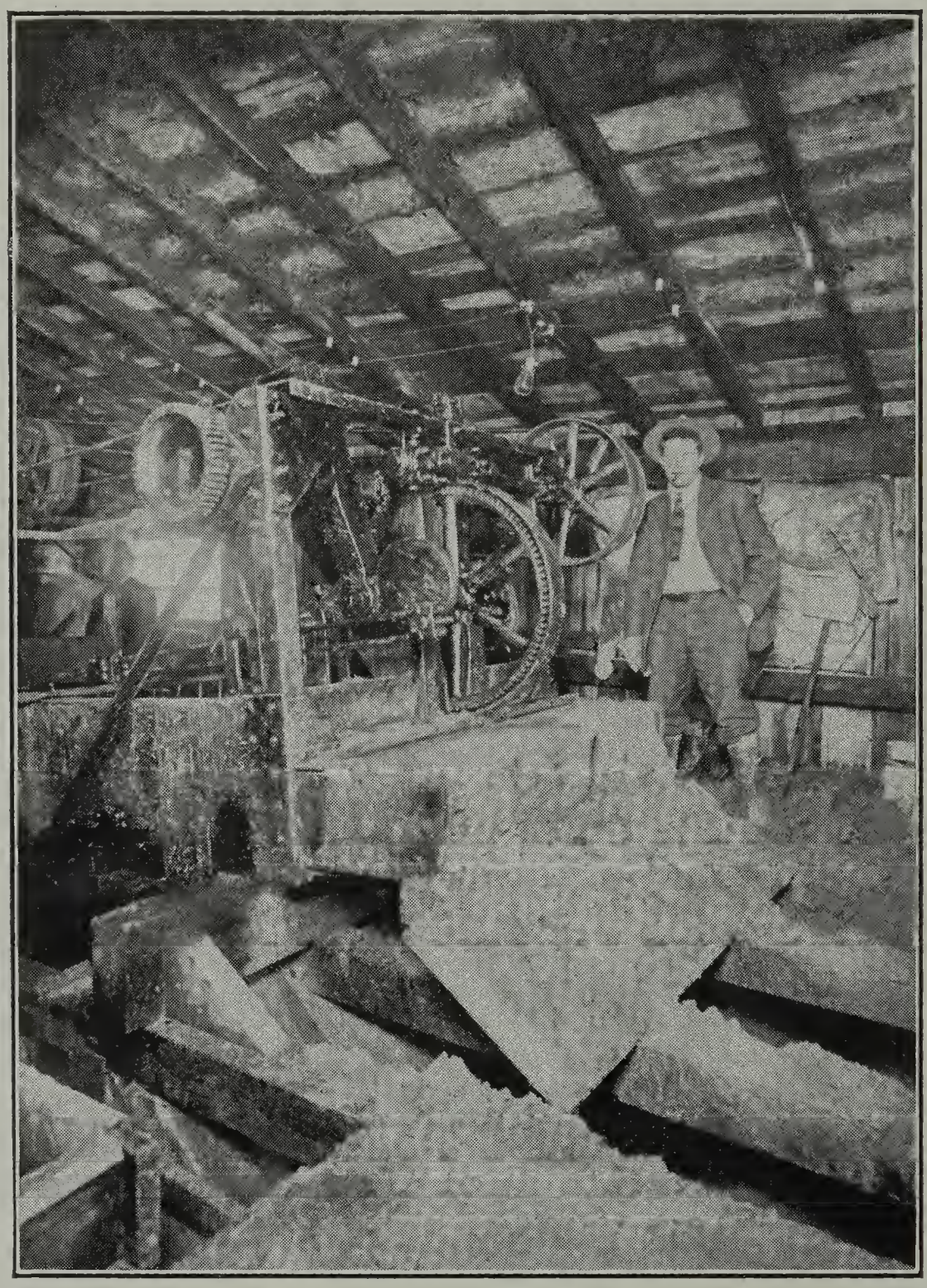


Fig. 3.—Tailing Discharge from the Last Machine of a Series of Acid-proof Classifiers Used for Leaching Copper Ore by the Butte-Duluth Mining Co.

some experiments were made along that line several years ago, but not carried to a conclusion. Last year Captain Wolvin, of the

Butte-Duluth Company, at Butte, who was leaching oxidized copper ores in vats there, brought up the same idea and we furnished him with five Classifiers for trial, with all parts subject to contact with the acid made of hard wood. These machines proved very successful, increasing the extraction over the former leaching in vats at least 20 per cent, and we have since then furnished this company with more machines for the same purpose. Fig. 3 shows the discharge of tailing from the last machine of a series.

I have been unable to get reliable detail results of these operations as they have been changing details from time to time, but the following data obtained last summer from the Butte-Duluth Company, when the first installation consisting of six small Classifiers was in use, and will give an idea of the operations at the time.

6 Classifiers in series; $5-15' \times 4\frac{1}{2}'$, $1-30' \times 4\frac{1}{2}'$.
Ore crushed through .12", opening in inclined impact screens, giving a product about -10 mesh.

Value of heads	2.14% Cu
Average strength, H_2SO_4 acid used	7.33%
Ratio of solution to ore	2.25 to 1
Moisture in discharged tails	20 %
Extraction	89.9%
Value of solution going to cells	1.8% Cu
Value of solution from cells	0.9% Cu
Speed of classifier rakes, strokes per minute	6
H.P. (Motor 80% efficient) total	4.6

The average daily capacity for the month in which the above figures were obtained was about 150 tons. The limit to the capacity was the lack of electrolytic cell room.

Spent electrolyte after strengthening was added to the first two Classifiers and water into No. 6. Most of the overflow from the latter went to scrap-iron precipitation and an amount equal to the acid liquor brought out from No. 5 with the ore was carried through Nos. 5, and 4 to No. 3, thus effecting a counter-current washing. The overflows from Nos. 1, 2 and 3, after clarifying, were sent to electrolytic precipitation. The ore received about 40 minutes' contact while passing through the whole series.

TRIPLE-WASHING CLASSIFIER

Fig. 4 shows a machine which we have designed to wash a sandy material absolutely free from any trace of slime or to wash the same kind of material entirely free from any liquid in which

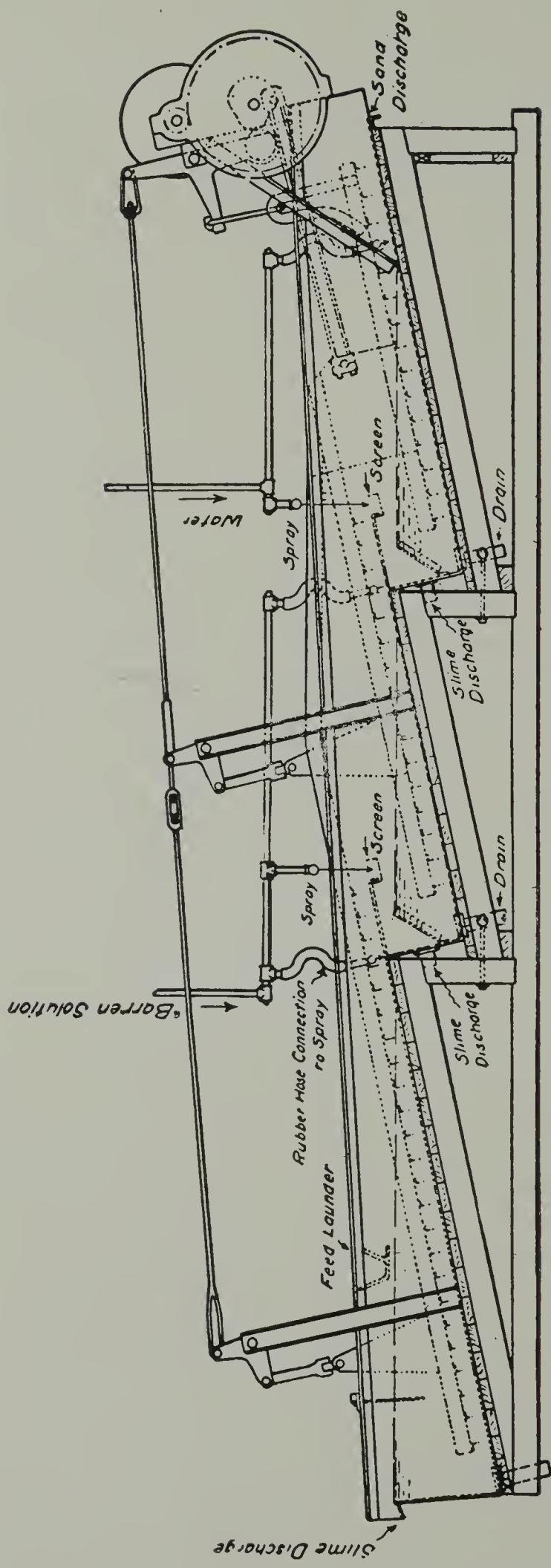


FIG. 4.—Triple-Washing Classifier.

it may be suspended. It will be noted that there are a number of opportunities to get rid of the liquid or slime. As the sand is raked up above the water level in each box it is sprayed with any solution, or water, and as it is washed into the following box it is diluted with the same liquid, so that in all it gets a very thorough treatment.

Possible Uses of the Classifier

Several Dorr Classifiers are now in operation at one of the mid-Western chemical works, used, I believe, for draining a granular chemical precipitate and washing same. Its use is now being considered in the preparation of a high-grade kaolin in place of the settling boxes which now require a great deal of labor for removing the sand from them, and its use for dewatering granular material from any liquid will be apparent.

THE DORR CONTINUOUS THICKENER

Developed by me in 1906, when, in remodeling a mill in the Black Hills I desired to thicken the slime pulp from classification, continuously, in large units and avoid the use of the large cones which accumulated solid slime on the sides and gave much trouble. The trial machine was operated in a tank 35 feet in diameter by 12 feet deep at a speed of $\frac{1}{20}$ R.P.M., and gave excellent results, continuing in operation until the mill burned, five years later.

Description

The Dorr Continuous Thickener, Fig. 5, consists of a slow-moving mechanism placed in a suitable tank, by means of which the operation of settling may be made continuous through the removal of the settled material to a point of discharge and the prevention of its accumulation as a solid in the tank.

As usually furnished, it consists of a central vertical shaft with radial arms equipped with scrapers to bring the thickened material to a discharge opening at the center by the slow rotation of the mechanism. The thick material may be discharged by gravity at this point into a launder, or piped to the side of the tank and raised by air lift or pump to the level of the overflow or higher.

The machine is arranged for raising the shaft so that the arms

will not be imbedded in the thick material if the power should be shut off for any length of time. The shaft can be lowered again gradually while running. Shaft and gear bracket are supported by a bridge over the tank or suspended from the roof trusses.

At the Liberty Bell Mill, Thickeners have been installed driven from below the tank through a mercury bearing, and have proved efficient, although they cannot be raised. The thin pulp is delivered near the center of the tank in a suitable well with a float to cause minimum disturbance, and the overflow is taken off by a peripheral launder.

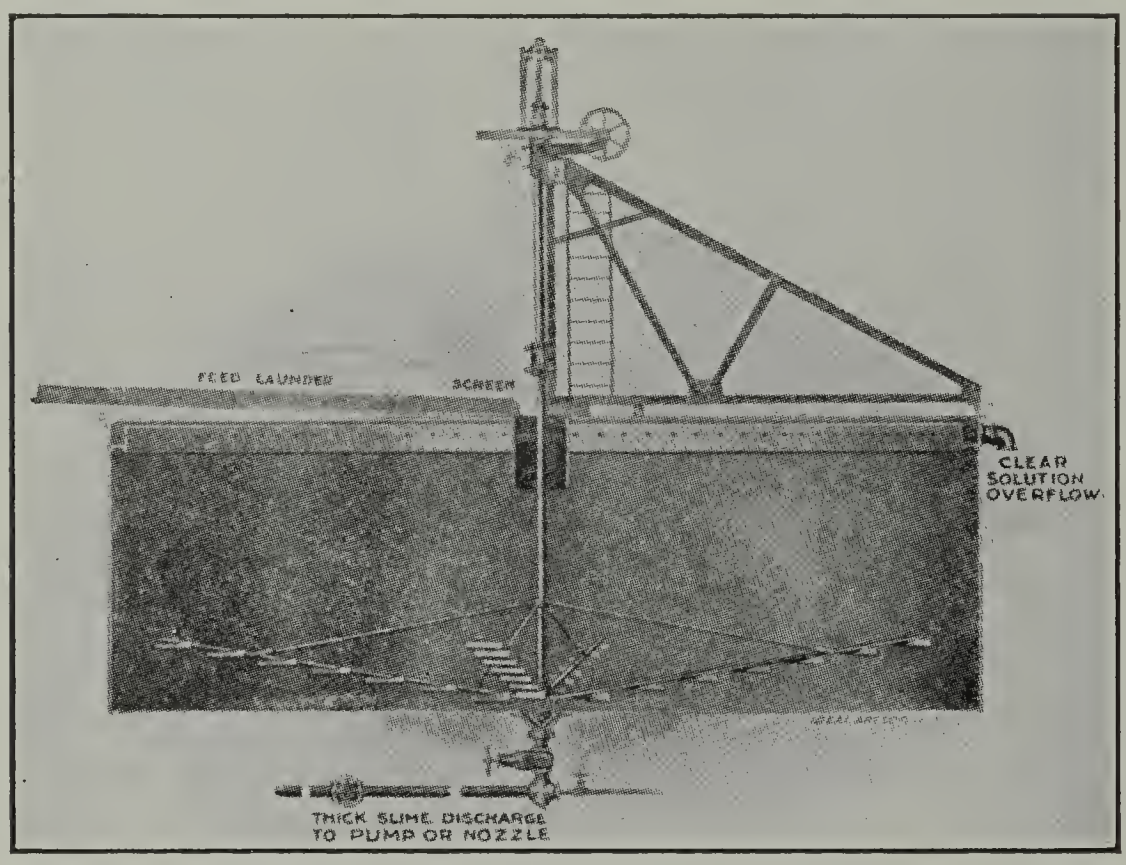


FIG. 5.—The Dorr Continuous Thickener (Patented).

The thickened pulp can be accumulated and withdrawn at intervals or a continuous discharge maintained as desired. Nozzle discharge is in use in some concentrating mills where a comparatively thin pulp is desired, and also in one case where a product of only 30 per cent moisture is being obtained. Many are using diaphragm pumps for this purpose. They have the advantage of ready regulation and require little attention. Having a positive displacement they tend to regulate automatically the amount of solids withdrawn, for, when the pulp becomes thicker, more solids are pumped with each stroke. A petcock to admit air into the suction has proved most satisfactory as a means of regulation.

Speed

The Thickener has been operated at speeds ranging from 1 revolution in 2 minutes to 1 in 40 minutes. A quick-settling sandy material will offer great resistance unless a comparatively high speed is maintained, while colloidal slime will give a slightly thicker underflow at a very slow speed. It will be found when handling sandy material that if the sand accumulates so that it is being moved around the tank by the channel arms as well as being advanced toward the center by the plows the resistance increases rapidly and the speed should be increased.

Power

This varies with the size of the tank and the nature of the feed. Of course, the motor input is much larger than the actual power consumed, owing to the low load factor commonly used, as it is essential to have power enough to meet an unusual strain. Spring measurements have shown approximately $\frac{1}{20}$ H.P. being transmitted to the worm shaft of a 44-ft. Thickener handling a classified slime. It would not be advisable, however, to install less than a 1 H.P. motor on a single machine, but $\frac{1}{2}$ H.P. each can be allowed when several are driven from one lineshaft.

Repairs

Normal operation of the Thickener causes no wear except on the worm, and many machines are running to-day that have not cost a cent for several years. On the other hand, if started after a shutdown without raising, a strain of any amount may be given so that the " weakest point " would have to yield.

The Overload Alarm, Fig. 6, is arranged to indicate the resistance offered by the mechanism as shown by the thrust on the worm shaft and to ring an alarm when the load becomes excessive. A solenoid or other means can be used to correct automatically the conditions causing the excessive load, by reducing the feed or increasing the underflow. The alarm has proved very valuable, especially on quick-settling pulp, when it is desired to obtain the thickest discharge.

Labor

The attendance required varies with the regularity of conditions maintained and is usually confined to lubrication once a shift, so that the care of the Thickeners is included in the duties of some man employed principally on other work.

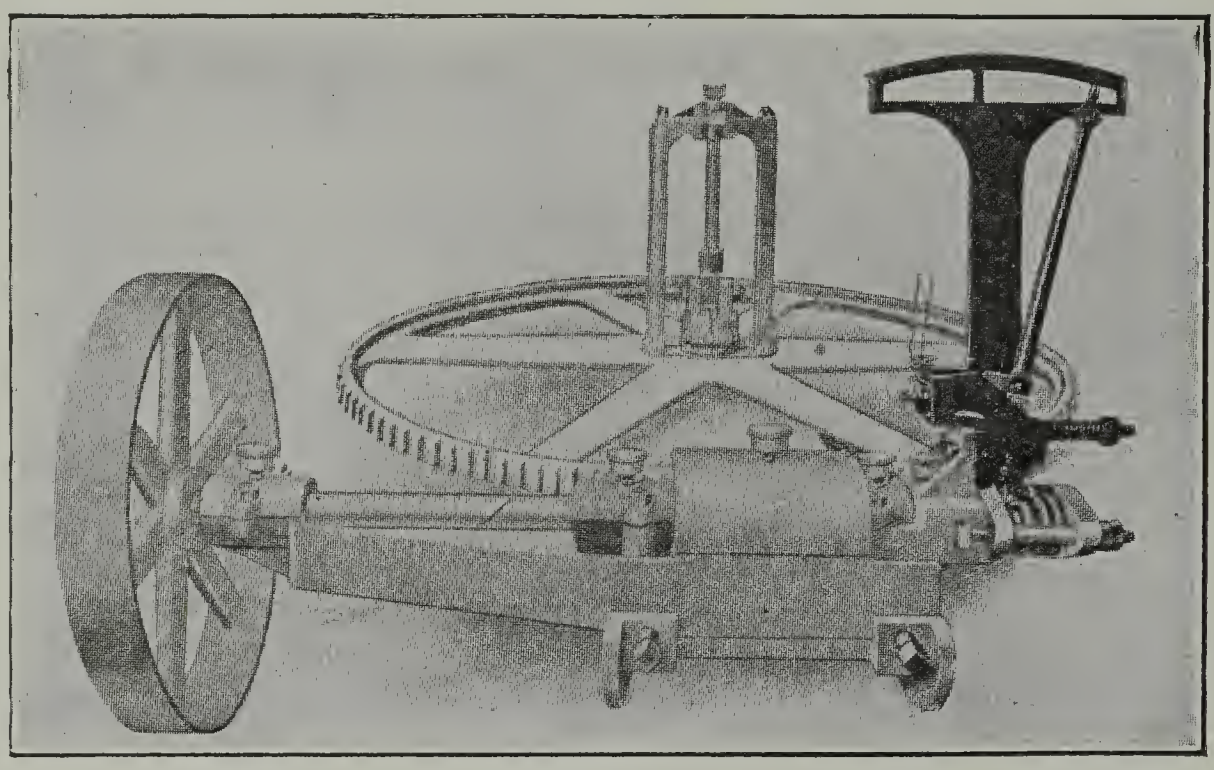


Fig. 6.—Overload Alarm and Resistance Indicator on Thickener with Arrangement for Raising Shaft while Operating.

Capacity

The capacity of Dorr Thickeners on any pulp has been found to be primarily a function of area, although the depth of the tank has an influence depending on the dilution of the feed and the dilution of the underflow desired. With a given area and depth and a very dilute feed and underflow the capacity depends on the amount of liquid that can be clarified, i.e., additional solids, but no additional liquid can be added to a tank already fed to capacity without overflowing slime. On the other hand, with a feed perhaps 8 of liquid to 1 of solids and a thick discharge of 2 to 1 or less, it will be found usually that additional liquid can be added to a Thickener operating at capacity without overloading it, but any addition of solids will cause slime to overflow.

If a plant requires more settling capacity, raising the temperature of the solutions may prove an economical way to add 10 to 20 per cent. The capacity of any filter can also be increased by this means.

The table following represents data given to me from time to time. It shows the settling area in use per ton in different mills which in many cases were not feeding their Thickeners at capacity.

OPERATING DATA ON DORR THICKENERS

Mill.	Sq.ft. Settling Area per Ton of Solids Thickened per 24 Hrs.	Sq.ft. Settling Area per Gallon Overflowed per Minute.	Remarks.
San Rafael, Mexico....	4.5	.....	Tube-mill product, 75% −200 mesh, discharge, 45.5% solids.
Liberty Bell, Colorado..	15.0	12.6	Tube-mill product, much light argillaceous slime. Discharge 33% solids: +100, 17%; +200, 13%; −200, 70%. Feed 9 : 1. Solution fed at capacity; solids not. Large area per gallon overflowed per minute due to density of underflow and nature of the slime.
Mogul, South Dakota. .	3.92	.....	Tube-mill product; ore siliceous: +60, 0.6%; +100, 7.8%; +200, 26%; −200, 65.6%; Discharge 56 to 59% solids. Continuous decantation.
Batopilas, Mexico.....	0.6 to 0.9	.....	40-mesh product; 90% passing 100 mesh.
Zambona, Mexico.....	3.1	.....	Tube-mill product. Discharge 40% solids.
Dominion, Ontario....	5.4	.....	Tube-mill product, 88% −200 mesh, ore diabase. Discharge 40% solids. Feed 6 : 1.
Porcupine-Crown, Ont.	4.25	.....	Tube-mill product, 75% −200 mesh. Discharge 65% solids. Quartz ore. Continuous decantation. With 5.1 sq.ft. settling area per ton settles to 71 to 73% solids.
El Palmarito, Mexico..	4.5	.....	Tube-mill product: pure quartzite, 97% −200 mesh. Feed 7 : 1. Discharge 65 to 70% solids. Continuous decantation.
Amparo, Jalisco, Mexico	4.9	1.4	Tube-mill product, siliceous: 93.5% −200 mesh. Feed 24.5 : 1. Discharge 23.5% solids: used to feed vanners.
Veta Colorado, Parral, Mex.	5.0	3⅓*	Tube-mill product, rather argillaceous: 71% −200 mesh. Feed 11 : 1. Discharge 33% solids for agitator. Have settled to 65% solids.
Smuggler-Union, Telluride, Colo.	.....	.....	Very clayey slime with classified sand. Screen test: +40, 1.48%; +60, 7.27%; +110, 14.81%; +200, 11.63%; −200, 65.81%.
	30.0	26.0	Settling from cold water, slightly alkaline. Feed 8 : 1. Discharge 50% solids, 1.429 sp.gr.
	10.0	.....	Settling from cyanide solution. Feed, 2.5 : 1. Discharge 40% solids, 1.316 sp.gr.
A large copper company, Arizona.	11.6	8.11	Considerable argillaceous slime. Feed 10.4% solids. Discharge 25.3% solids.
Pennsylvania Steel, Lebanon, Pa.	14.2	2.48	Thickening ahead of vanner concentration. Feed 2.8% solids. Discharge 10.6% solids. Overflow 0.4% solids, extremely fine, which does not interfere with using water again.
Nevada Consolidated, Ely, Nevada	.....	1.25	"Each 17-ft. thickener supplies wash water for 20 Wilfley tables and occasionally for wash on vanners. One thickener has a greater capacity than twelve 8-ft. cones." Area of 17-ft. tank is 226 sq.ft.; of the twelve 8-ft. cones, 525 sq.ft.

* Not up to capacity of overflow.

OPERATING DATA ON DORR THICKENERS—*Continued*

Mill.	Sq.ft. Settling Area per Ton of Solids Thickened per 24 Hrs.	Sq.ft. Settling Area per Gallon Overflowed per Minuute.	Remarks.
Broken Hill, Proprietory, Australia	.....	1.80	Dewatering slime from lead-zinc concentration mill. Feed 100 : 1. Discharge 55% solids
Anaconda Copper, Mont.	.....	5.95	Dewatering slime from concentrator. Forty 4-deck thickeners, each 28 ft. in diameter by 3 ft. 3 in. deep, handle about 26,000,000 gals. of pulp per day which contains approximately 2% solids. A clear overflow obtained, the underflow containing about 15% solids, which is fed to buddles.

The data given here show that when pulp is carried in cyanide solution a provision of 5 to 6 sq.ft. per ton for a siliceous tube-mill product is ample and from 7 to 15 sq.ft. for a clayey material or classified slime product. When very dilute products are handled the area required is determined usually by the gallons per minute to be overflowed.

Density of Underflow

This depends on the nature of the pulp to be settled and the size of the particles. An argillaceous pulp, such as that at the Liberty Bell in Colorado, although containing a large percentage of reground siliceous material will not settle thicker than 60 per cent moisture, while a finely round quartz will give as low as 27 per cent moisture. At the Porcupine-Crown plant, handling a quartz product of 75 per cent minus 200 mesh, the average final pulp discharged contained 30 per cent moisture with the feed at the rate of 1 ton of solids per day for each 4.7 square feet of tank area.

We have no reason to think that the use of the Dorr Thickener will increase the amount of water that can be clarified in a given settling area at the beginning of the flow into the tank, but the removal of the pulp as rapidly as it settles certainly avoids the decrease in the settling rate which would follow when a tank is filling up in intermittent settling.

At one plant where reground ore pulp was thickened from 10 to 1 to approximately 2 to 1, actual experience indicated that the change from intermittent to continuous settling enabled three tanks equipped with Dorr Thickeners to do the work of five used intermittently.

THE DORR TRAY THICKENER

The original Thickener was installed in a tank 12 feet deep and we adhered to approximately that depth, varying from 6 to 16 or 20 feet, for a number of years. One reason for this was that it early showed itself to be an advantage to have ample storage capacity for thickened slime at the bottom of the tank. It not

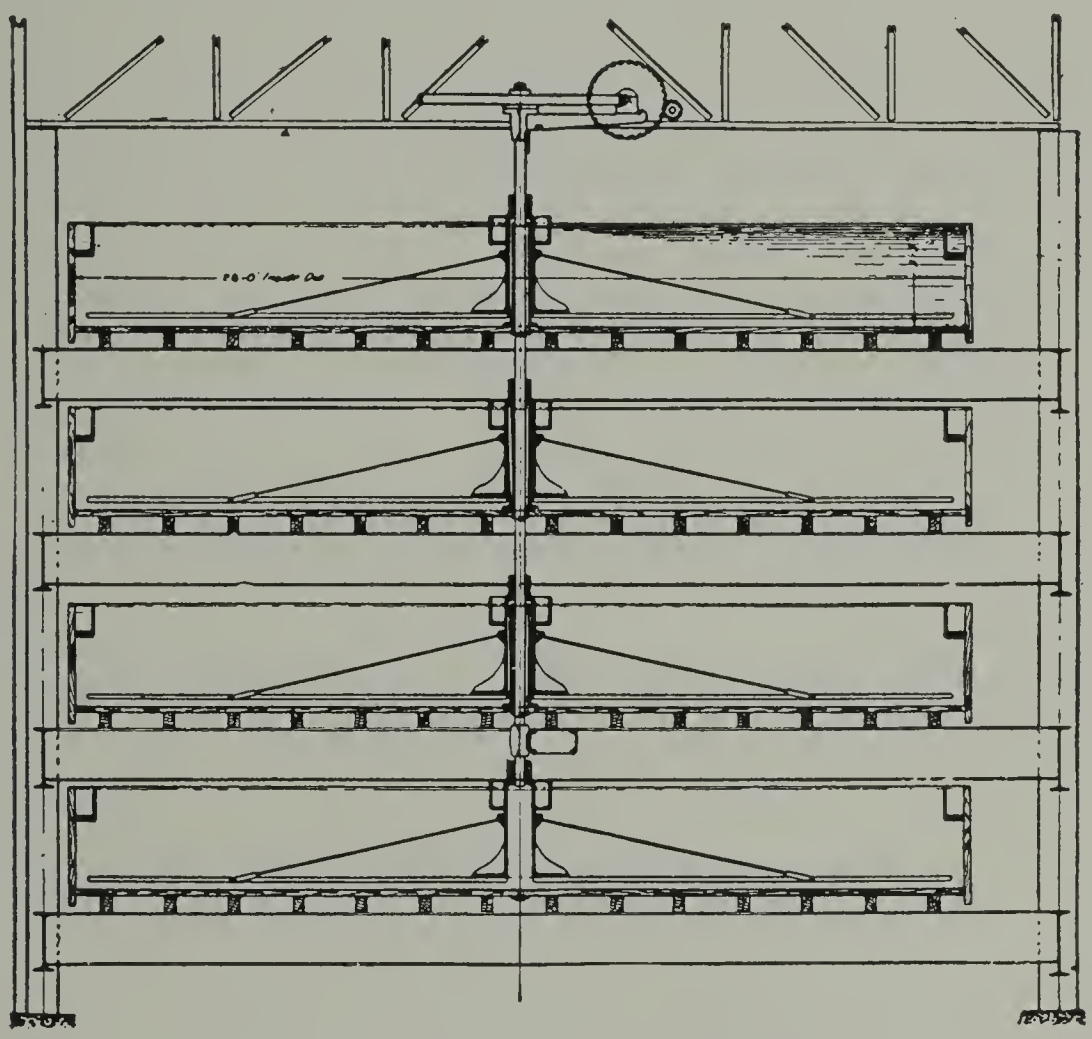


FIG. 7.—The Dorr Tray Thickener (Patented): Superposed Type.

infrequently happens that the flow of slime to the settling tank will vary during the day and the settling qualities of the slime vary as well, so that if the feed is light a large quantity of clear liquid accumulates on the top of the Thickener which, when more slime comes, flows away together with the freshly clarified water and partly thickened slime takes its place, thus giving a great reserve capacity. In 1913, however, I had occasion to go into the question of securing large settling capacity with small floor space and developed what I have called a Tray Thickener. There are two types of this. The first, which would seem to be the simplest, has been installed by the Anaconda Copper Company and in the Cœur

d'Alenes. It consists of two or more shallow tanks, each carrying thickening apparatus attached to a common shaft and acting as independent units with its own feed, clear water overflow and thick slime discharge. Tests made by the Anaconda Copper Company indicated that with their material, tanks 28 ft.×3 ft. would handle approximately 90 per cent of the material that tanks 28 ft.×9 ft. would handle, so that this gives them a great economy in plant construction. Fig. 7 shows this type and represents one of forty Tray Thickeners installed in their settling plant which is handling 26 million gallons of water a day and separating therefrom 2600 tons of extremely colloidal slimes.

The second type of Tray Thickener, which I have called the submerged type, was tested first at the Homestake Mill at Lead,

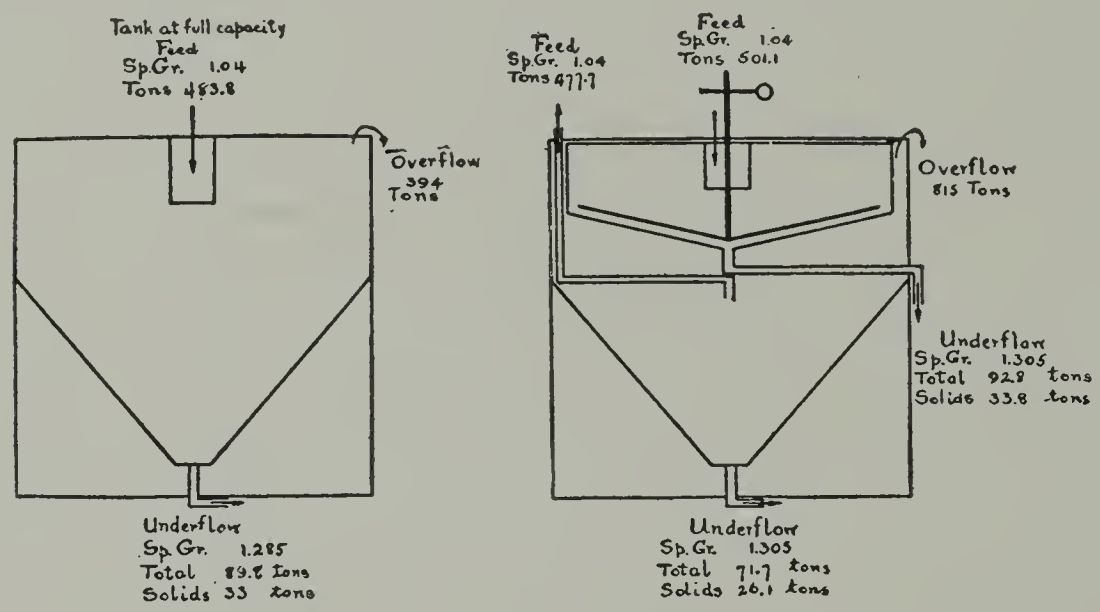


FIG. 8.—Test of Tray Thickener at Hometake Mill, Lead, S. D.

South Dakota, and consisted as tried there essentially of a shallow Thickener and tank entirely submerged in a cone-bottom settling tank. The space below the small Thickener had its own feed and discharge and the clear water water overflowing from it joined the overflow of the shallow Thickener tank. The latter has its own feed and discharge as well.

The drawings shown, in Fig. 8, give the result of tests made there to show comparative capacities of tanks with and without the tray. Applying the idea to Thickeners already installed, Fig. 9 shows the installation of a tray in a standard deep Thickener. It gives in effect two tanks each with its own feed and discharge and a combined overflow, and in practice has resulted in enabling us to add 70 to 100 per cent to the capacity of plants already in

operation. It has been found unnecessary to make this tray strong enough to support these tanks filled with liquid if the space below it is empty as by means of an automatic float we have arranged to make connections between the upper tank and the lower in case the level of the liquid drops in either. It will be evident, I think, that these trays will afford means of obtaining a large amount of settling capacity with comparatively small floor space and we are working now on their further development.

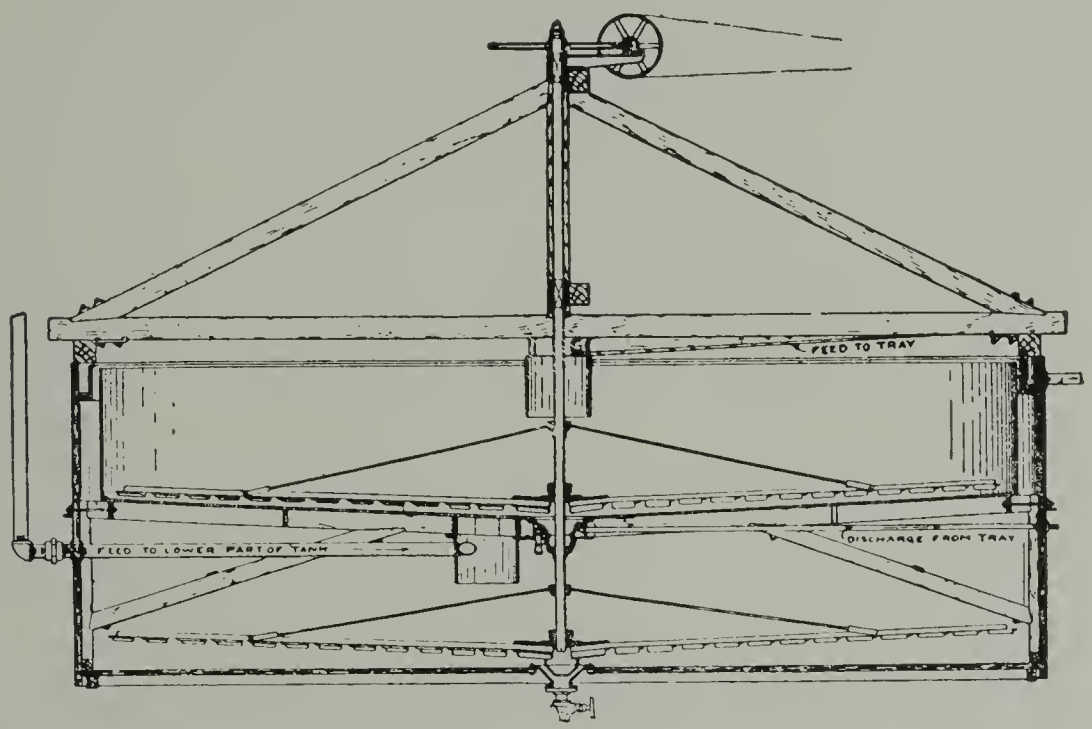


FIG. 9.—The Dorr Tray Thickener (Patented): Submerged Type.

LARGE THICKENERS

For a long time the largest Thickeners in use were in tanks 50 feet in diameter by 20 feet deep at the Nevada Consolidated Company. Within the last year, Mr. David Cole, the constructing engineer of the Arizona Copper Company, designed and installed a Dorr Thickener in a tank 130 feet in diameter. Fig. 10 shows the machine in operation. It has proven entirely successful and indicates the possibility of furnishing very large units which will cost less per square foot of settling area than the smaller ones. The tank in this case is merely a ring of concrete erected on a slag dump, the settled slag forming its own bottom. Tanks built along these lines with dirt bottom and walls of concrete or wood will aid materially in reducing costs of installation. It is probably as large as we would care to build, but we anticipate building up to 100 feet, using the bridge and central shaft, which we now use

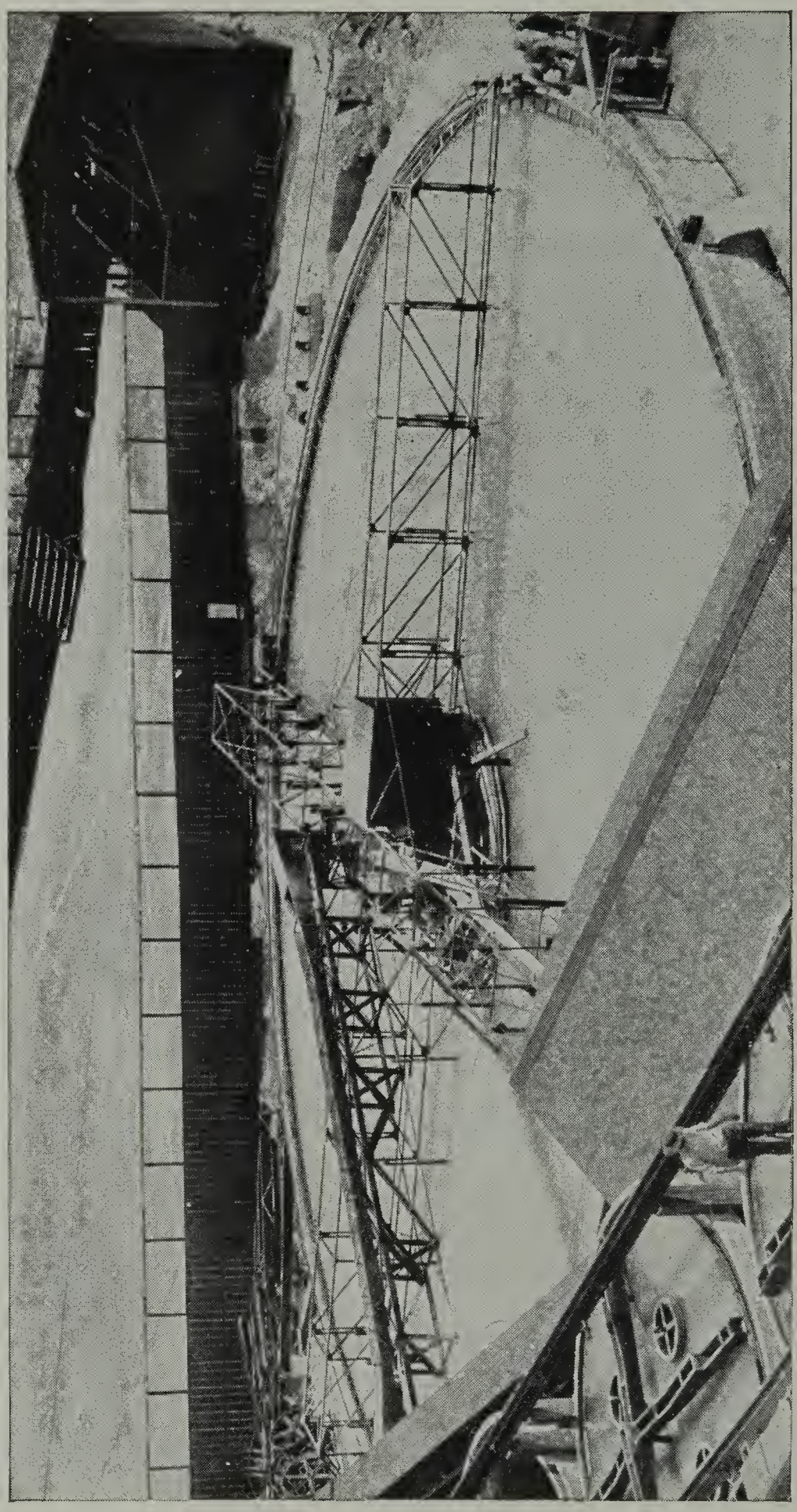


FIG. 10.—The Dorr Thickener in Tank 130 Feet in Diameter at Arizona Copper Co.'s Mill.

on our standard machine. This large Thickener has handled over 1200 tons of solids per day and Mr. Cole estimates that it would take care of 2000 tons of material 40 mesh and finer. Its overflow has been over 3,000,000 gallons per day and its limit of capacity has not yet been reached. The net saving in water by the use of this machine with the mill at capacity is $120 per day.

Uses

The Thickener was originally introduced in cyaniding for thickening slime or reground pulp previous to agitation and filtration and came into general use for that purpose. Within the last few years it has proved a means for recovering the dissolved values as well by Continuous Counter-current Decantation, which will be spoken of later. Its use in thickening ahead of slime concentration has become very general, nearly all the large copper and lead companies having adopted it withing the last few years. The development of flotation has also found a new use for it in connection therewith at most of the plants that have recently been installed in this country and in Australia.

Industrial Uses

The Thickener presents great opportunities for the recovery at an extremely small expense of all kinds of finely divided residues that go to waste or are recovered intermittently from settling ponds. The expense including interest on equipment amounts in one case to one mill and in another two mills per thousand gallons clarified. In both cases the solids removed are colloidal ore slimes. One plant recovering a finely divided organic material from settling ponds substituted the Dorr Thickeners for them and, I am advised, save the labor of 12 men per day. Its use for removing heavy silt in water purification seems possible with the large units now feasible.

Its use for sewage sedimentation and for the prevention of stream pollution looks promising. A plant is now planned for the recovery of precipitated ferric-hydrate from mine water.

In all industrial work its use to furnish a much thicker product to a filter press will mean great increase in the capacity of the press with diminished costs.

CONTINUOUS COUNTER-CURRENT DECANTATION

Continuous Counter-current Decantation consists of so operating a series of settling vessels that the solids to be treated, continuously pass through them in succession, being diluted after each thickening by solution from the overflows passing in the opposite direction. The objects to be attained are the dissolution under most favorable conditions of a portion of the solids, the separation of a solution from a finely divided solid with minimum dilution, or both combined.

The last result is that usually obtained in metallurgical work as the separation of most of the dissolved material from the solids always occurs and even when apparently adequate means for dissolution are provided ahead of the system the favorable conditions afforded usually give an additional extraction.

History

The principles of Continuous Counter-current Decantation, are very old and have been applied in many ways in chemical technology as well as in metallurgy. The first cyanide plant using this method in the United States was erected by John Randall in the Black Hills in 1902, using large cones for settlers, and was operated for a year. The invention of the Dorr Thickener in 1906 gave an opportunity to avoid the troubles inherent in cones, and in 1910 the first modern plant was started. Since that time there have been a large number of plants installed, several of them replacing vacuum filters, so that it may be regarded to-day as one of the well-established methods of cyaniding. Several years ago Dr. R. Gahl successfully operated an experimental plant with cone settlers leaching copper ore slimes with sulphuric acid, treating 7 or 8 tons daily, to which he refers in a paper he read before the American Electro-Chemical Society, April, 1914. A test plant of 75 tons capacity is now starting, using Thickeners.

The following description of a typical flow sheet of a Continuous Counter-current Decantation cyanide plant will undoubtedly explain the process further and also show the method we have used to determine the results that may be expected from any conditions assumed.

The square marked MILL, Fig. 11, represents the grinding machinery, and we assume the ore is crushed in cyanide solution

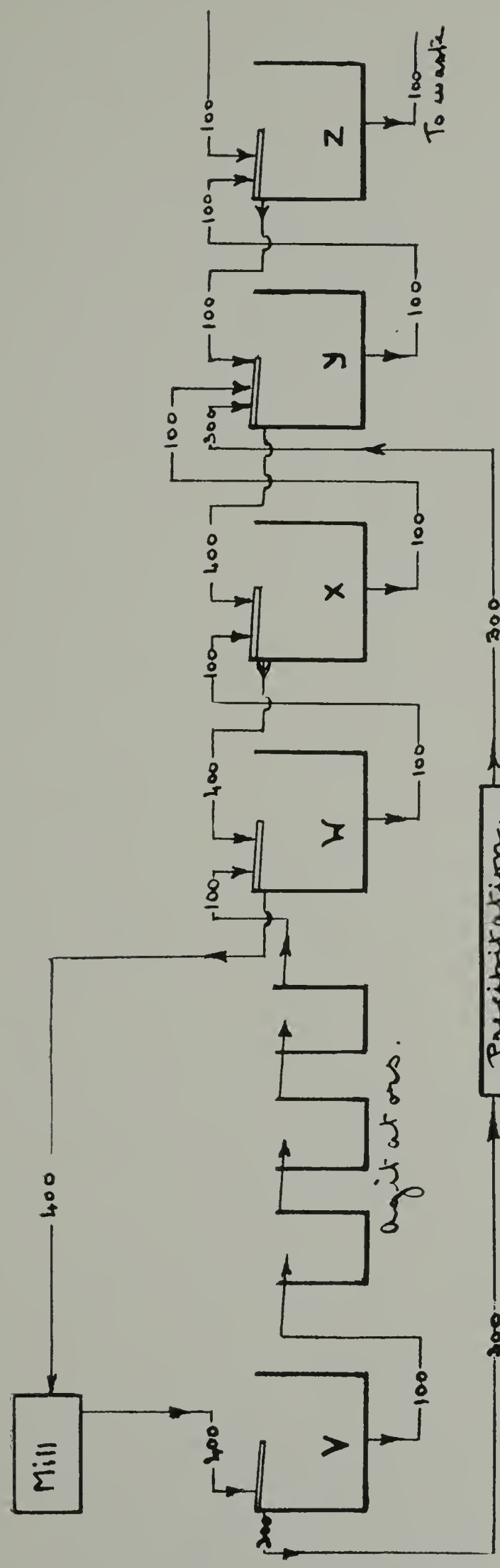


FIG. 11.—Example of Continuous Counter-current Decantation for Cyanide Plant.
Figures Refer to Solution Tonnages.

which brings the fine pulp continuously into Thickener V from whence the solids pass through the Agitators and Thickeners W, X, Y, and Z, until discharged from Z as tailings.

The following conditions are assumed:

1. The thick pulp underflows are thoroughly mixed with the clear overflows before entering the next tank so that the dissolved gold is uniformly distributed through the liquid.

2. One hundred tons of ore are milled per day.

3. \$8.00 is dissolved per ton; 75 per cent in the mill, the balance in the Agitators.

4. The pulp from all Thickeners is discharged at a ratio of 1:1, or 50 per cent moisture.

5. Three hundred tons of solution is precipitated to a value of \$0.02 per ton.

To determine the value of the solution from any Thickener, if V, W, X, Y, Z, equal the value in dollars per ton of the solution leaving each Thickener, we get the following equations, as the same amount of gold and solution will enter and leave each tank:

$$(1) \qquad 400\,W + (\$6.00 \times 100) = 300\,V + 100\,V$$

That is, the gold in W plus the additional gold assumed to be dissolved in the mill equals the overflow and underflow of V.

$$(2) \qquad 100\,V + (\$2.00 \times 100) + 400X = 400\,W + 100\,W$$

The ($\$2.00 \times 100$) represents additional gold dissolved in the Agitators.

$$(3) \qquad 100\,W + 400\,Y = 400\,X + 100\,X$$

$$(4) \qquad 100\,X + 100\,Z + (300 \times \$0.02) = 400\,Y + 100\,Y$$

$$(5) \qquad 100\,Y + 100 \text{ water (no value)} = 100\,Z + 100\,Z.$$

In No. 4 the \$0.02 represents the value of the precipitated solution returned to Y.

No. 5, representing a simple dilution with water, means that Z will have one-half the value of Y.

Solving these equations we get the following values:

$$V = 2.673, \quad W = 1.173, \quad X = 0.298, \quad Y = 0.079, \quad Z = 0.039,$$

which may be checked as follows:

The gold precipitated, ($2.673 − $0.02) × 300	$796.00
Lost in tailings, ($0.039 × 100)	3.98
Total	799.98
Total assumed dissolved (100 × $8.00)	800.00
Discrepancy due to decimals	.02
From the above we deduce:	
Assay value of solution precipitated	$ 2.673
Dissolved loss per ton solution	.039
Dissolved loss per ton ore	.039
Percentage dissolved gold recovered	99.5

Similar calculations have shown that if one Thickener is omitted from the flow sheet and no other conditions are changed the dissolved loss is increased to $0.133. Using the same four Thickeners and precipitating 400 tons, instead of 300, the loss is cut to $0.08, while if the pulp can be discharged with 60 tons of solution, instead of 100, making it contain 37 per cent moisture, the amount precipitated can be reduced to 240 tons and the loss will only be $0.076 per ton of ore, although the solution precipitated will assay $3.321.

I should explain here that the reason the precipitated solution is added at *Y*, instead of *Z*, where it would obviously be more effective in increasing the extraction of gold, is that we have also a mechanical loss of cyanide to contend with. The 100 tons of water which can be added at *Z* to replace the liquid discharged with the tails reduces the strength of the solution lost to one-half when added to 100 tons of cyanide solution, whereas if added to 400 tons of solution it would reduce it only to four-fifths. A further saving in cyanide can be made by adding the barren solution at *X*, but this usually means adding an additional Thickener on account of excessive gold losses.

It will be noted from these figures that the loss in gold can be regulated at will by increasing the solution precipitated or the number of Thickeners in the series, and also that pulp settling to 30–40 per cent moisture can be treated much more efficiently than pulp settling to 50–60 per cent. If pulp cannot be settled to 50 per cent or thicker it will usually be profitable to use a filter merely for dewatering at the end of the series.

Details of Plant

Figure 11 and what has already been said about Dorr Thickeners will give a clear idea of the construction of a Continuous

Counter-current Decantation plant. The tanks in the series are either arranged on a level, in which case both the overflow and underflow must be elevated before being transferred into the next tank, or in a series of steps so that the overflow goes by gravity from tank to tank and only the smaller quantity of underflow is raised each time. Each method has its advantages.

Transferral of Pulp

Is preferably done by a diaphragm or other pump of fixed displacement as thereby a certain amount of automatic regulation is obtained.

Storage Tanks

The more a flow sheet and the actual conditions of mill operations are studied the less additional storage capacity is felt necessary.

Results

I realize that details of the technical results obtained in cyaniding will not be of great interest to chemical engineers, so will only say that when working on a hard, quick-settling ore ground to pass an 80-mesh assayers' screen or finer, which can be settled to a thick product containing 35 per cent to 50 per cent moisture, it has proved a most efficient means for the recovery of dissolved gold and silver from the pulp.

Compared with the usual filtration methods it has shown lower operating costs in spite of a higher mechanical loss in cyanide, and a higher recovery due to a lower loss of dissolved values and often to an additional extraction being made that could not be made commercially by direct agitation.

The following quotation from an article on Continuous Counter-current Decantation in the Engineering and Mining Journal of October 31, 1914, sums up the conclusions reached at the Gold Road Mill where Continuous Counter-current Decantation was installed to replace a vacuum plant:

"The operators state that the principal disadvantage they found with the vacuum-filtration system upon their ores was that it was almost impossible to wash satisfactorily the cakes on the leaves. Cakes of uniform resistance could not be formed. They would crack badly and large sections would fall from them, making

satisfactory washing impossible. Besides, the expense of labor, repairs, and power is considerably more than is necessary in following the Counter-current Decantation system. They find practically no difference between the two systems in the amount of cyanide and lime consumed, perhaps a slightly greater quantity, amounting to about 0.1 lb. of cyanide, is being consumed in the decantation system.

"An advantage found with counter-current decantation is that the dissolution of gold is so perfect, due to the longer contact between the solutions and the pulp. The difference, considering all things, between leaf filtration and counter-current decantation is at least $0.60 per ton of ore treated in favor of the latter."

This figure is higher than could be expected under usual conditions, but we have had definite statements of savings from the other plants that have changed as well. Information I have received from a number of plants operating indicate that on quick-settling ore from which $5.00 to $20.00 is recovered the mechanical loss in gold varies between 4 and 10 cents per ton of ore.

GENERAL CONSIDERATIONS

Dissolution and Recovery

From the nature of the process it is apparent that its use for dissolution is antagonistic to its use for recovery of the dissolved material, and although some have proposed the alternation of Agitators and Thickeners I have always advocated where a high per cent of recovery in a concentrated form was required as in cyaniding, all dissolution possible should be made ahead of the system. In other cases, as that described by Dr. Gahl, where it was essential to make the dissolution in stages so as to end with a nearly neutralized liquid and have the copper pulp when nearly finished meet fresh acid, it is of course essential, but calls for one series on dissolution and another on washing.

Scale of Operations

It will be seen that any continuous method of treatment of materials has greater relative advantages with an increase in size of operations and a Continuous Counter-current Decantation plant with 50-foot tanks will require no more labor, and, in fact,

less than one with 10-foot tanks, although it will have 25 times the capacity. As the actual labor cost for operating a series of Thickeners is less than one man a shift, it will be seen that if any washing or leaching operation is requiring the full time of one or more men this method can be considered, if other conditions are favorable.

Other Applications

Fig. 12 is intended to show a copper problem which I think will correspond to many problems that may occur in chemical

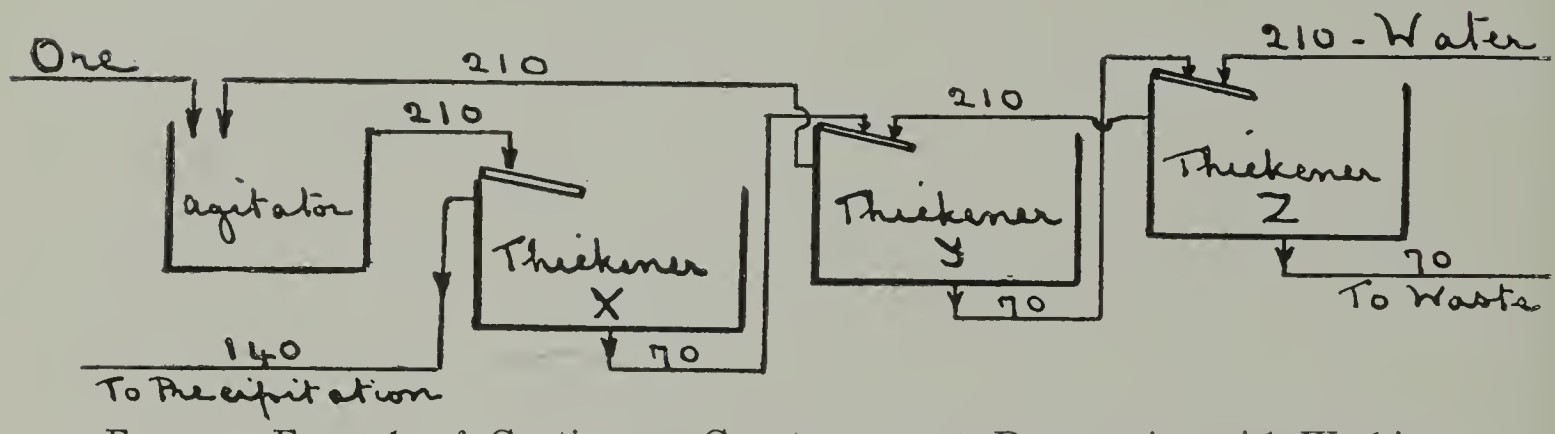


Fig. 12.—Example of Continuous Counter-current Decantation with Washing Liquid Not Reused.
Figures Refer to Solution Tonnages.

industries, namely, the complete washing of finely suspended solids and the obtaining of the dissolved material in as concentrated a form as possible from which it is to be recovered by evaporation or complete precipitation or by any other method, so that none of the liquid has to be returned to the system as in cyaniding.

Conditions Assumed

a. One hundred tons of oxidized copper ore slimes treated per day.

b. Slimes contain 2 per cent of soluble copper or 40 lbs. of copper per ton.

c. Pulp is discharged from all Thickeners with 41.2 per cent moisture.

d. Inflow to each Thickener is thoroughly mixed before entering same.

e. Two hundred and ten tons of wash water added to Thickener *Z*. The total overflow from Thickener *X*, 140 tons, sent to pre-

cipitation and 70 tons sent to waste with the discharged residues from Thickener Z.

f. Let X, Y, and Z represent the pounds of copper per ton of solution discharged from the respective Thickeners.

If we equate the inflow and outflow of each Thickener in terms of tonnage and copper contents we have:

(1) $$70X + 140X = 210Y + (100 \times 40 \text{ lbs.}),$$

(2) $$70Y + 210Y = 70X + 210Z,$$

(3) $$70Z + 210Z = 70Y + 210 \text{ tons of water.}$$

Simplifying and solving we obtain:

$X = 27.5132$ lbs. copper per ton of solution,
$Y = 8.4656$ lbs. copper per ton of solution,
$Z = 2.1164$ lbs. copper per ton of solution.

From the above the following results are deduced:

1. Overflow to be precipitated, i.e., X, contains 1.37 per cent copper, or 27.5 lbs. per ton of solution.

2. Solution wasted with the residues, i.e., Z, contains 0.10 per cent copper, or 2.1 lbs. per ton of solution.

3. Copper sent to precipitation = 96.3 per cent of that dissolved.

4. Pounds of copper lost per ton of slimes = 1.48 lbs.

Varying the number of Thickeners used and solution tonnage sent to precipitation, and assuming conditions *a*, *b*, *c*, and *d* remain constant, we obtain the following results:

Number of thickeners used	3		4		3		4	
Tons of solution sent to precipitation	140		140		210		210	
	Lbs. per Ton.	%	Lbs. per Ton.	%	Lbs. per Ton.	%	Lbs. per Ton.	%
Copper in the solution for precipitation	27.5	1.37	28.2	1.41	18.7	0.93	18.8	0.94
Copper in the solution wasted with the residues	2.1	0.10	0.7	0.03	0.9	0.04	0.2	0.01
Lbs. of dissolved copper lost per ton of slimes	1.48		0.49		0.63		0.16	
Per cent of dissolved copper sent to precipitation	96.3		98.8		98.5		99.6	

It is apparent from this that the enriched solutions, which contain 96.3 per cent of the soluble copper, will carry 1.37 per cent

copper per ton and that you get no weak liquors at all for further handling. The additional tabulations show the results of changing various factors. You will see from this that precipitating 140 tons of solution, but adding a fourth Thickener, increases the percentage recovered from 96.3 per cent to 98.8 per cent with an enrichment of the solution from 1.37 per cent to 1.41 per cent. Precipitating 210 tons of solution, on the other hand, shows a solution to be precipitated carrying 0.93 per cent copper with three Thickeners and 0.94 per cent with four Thickeners, while the percentage of recovery is 98.5 per cent and 99.6 per cent. In other words, it is easy to see that by using the proper number of Thickeners you can make practically any recovery desired and get any concentration you wish.

This method could be applied as readily to the manufacture of caustic from soda ash and lime, and I can say that a plant to use it to some extent has been purchased abroad, but its installation has been delayed by the war. As the reaction between the soda and the lime requires a definite time it is possible that it might be necessary to do it in charges, but the same was believed true in cyaniding until it was demonstrated that continuous agitation with a series of Agitators was better.

THE DORR AGITATOR

This machine, Fig. 13, was designed by me in 1910, but did not come into actual use until 1912, when about a half dozen machines were put out for trial purposes on a working scale at several different plants. The results obtained were so good that last year many more were installed in this country and abroad. During 1914, although mining in general has been very quiet, the use of them has increased greatly and from all installations made we have had nothing but satisfactory reports. The illustration will give a good idea of the machine, which is very much like the Dorr Thickener, the central shaft being replaced by a pipe at the top of which distributing launders are arranged to distribute the pulp which is raised through the pipe by means of air. A worm and sheaves provide means for raising or lowering the hinged arms at will. In cyanide metallurgy mechanical sweeps in flat-bottomed tanks were first used for agitating the pulp, but the great difficulty experienced in most cases with these, including

breakages and the power required, made the use of a high cone tank with a central air lift seem most attractive, and when it was introduced into this country and Mexico from Australia a very large percentage of the mills installed it. At this time agitation was done in charges, but when continuous agitation became the established practice a few years ago it was found that there was a great tendency for the coarser material in the pulp being agitated to build up on the sides of the 60-degree cones used, so that eventually

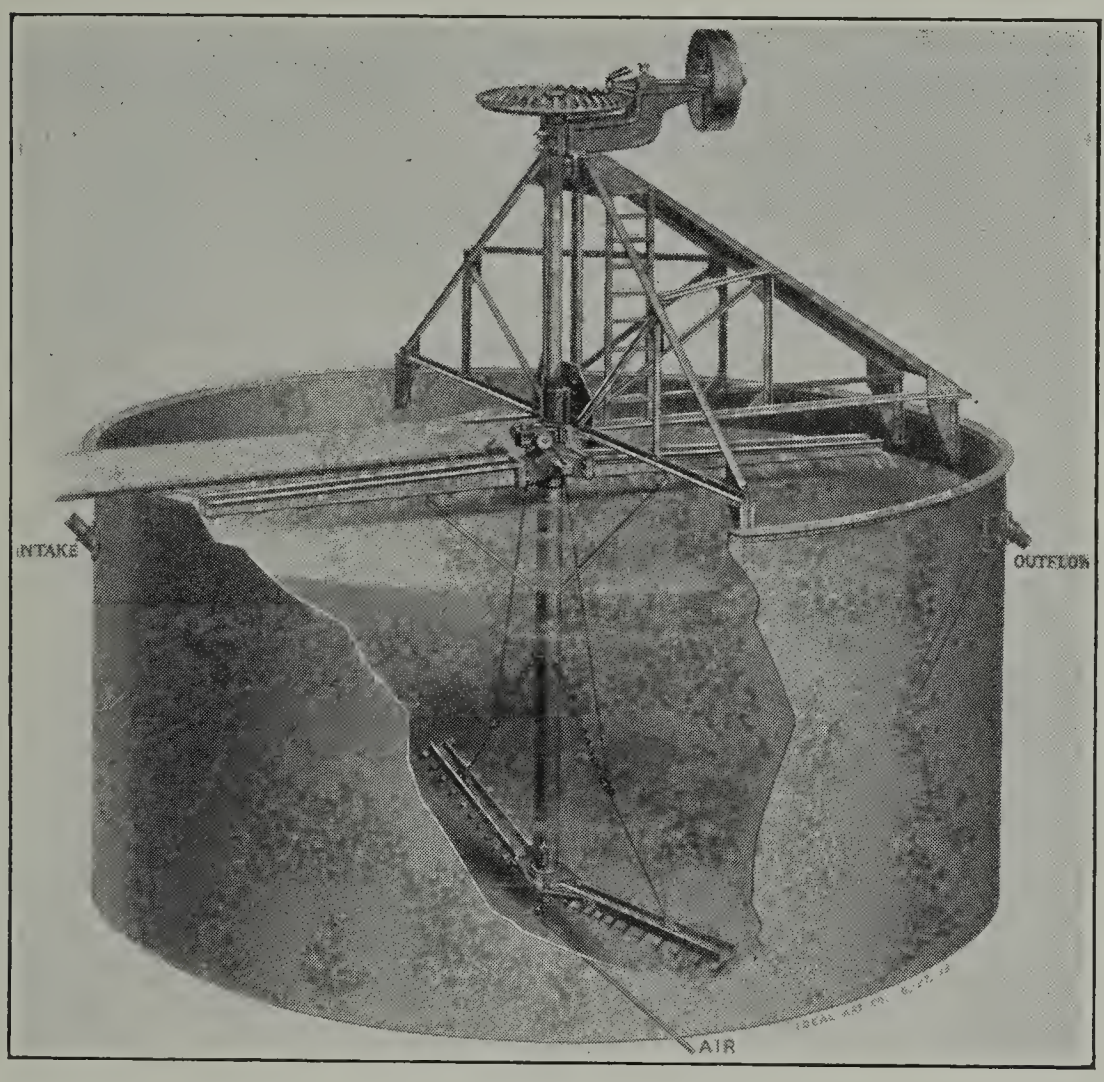


FIG. 13.—The Dorr Agitator (Patented).

the major portion of the agitating area became filled up with solids and the agitation only took place in a small cylinder in the center. It was also found necessary to give a much more violent agitation than the chemical treatment of the ore required in order to keep the pulp in suspension as much as possible. The Dorr Agitator, by the use of mechanical arms with the Thickener plows on, which prevents settling of solids and brings the material from the bottom to the central uplift pipe, allows the regulation of the intensity

of the agitation given to suit the chemical need of the ore and not the necessity for keeping everything in suspension.

Efficiency

The value of an agitator depends on the cost of making the maximum economic extraction by its use. This will be determined by its cost of agitation per ton per hour and the time required to obtain dissolution. All the data I have been able to obtain indicates that the cost of agitation per hour is extremely low. Extraction tests that have been made indicate that the rate of dissolution on both gold and silver ores in Dorr Agitators, with a uniform, although less violent agitation, is at least as rapid as in any other agitators with which it has been compared.

The most favorable conditions for the dissolution of gold and silver in cyanide solution vary with each ore treated. The maintenance of an excess of dissolved oxygen throughout the whole mass of pulp and the free movement of all particles of solids in the liquid immediately adjacent seem to be the only conditions that can be generally specified. Definite work both in milling and the laboratory indicate that many ores will give a more rapid extraction and allow the use of a weaker solution when agitated as a dilute pulp of 3 to 1 or 4 to 1, and also cause less chemical consumption of cyanide.

The Dorr Agitator, with its combination of air and mechanical agitation, gives a flexibility that is apparent and it insures keeping all the solids in suspension all the time whether the pulp is subjected to a gentle or a violent movement. This is essential, especially in continuous agitation.

Selective Agitation

The question of selective agitation was discussed by Mark R. Lamb [1] in the Transactions of the American Institute of Mining Engineers. As used here the expression is taken to mean continuous agitation under conditions which cause the coarser particles of the ore to remain in the Agitator longer than the average time of treatment and thus give them the longer exposure they may require to obtain the best extraction.

[1] Trans. A. I. M. E., xi, 775 (1909).

This can be accomplished readily with the Dorr Agitator by agitating at a dilution which allows the coarser material to classify out and discharging the raised pulp near the center while the outflow is taken from near the periphery. It will be seen that if a segregation takes place and the Agitator is fed a pulp carrying 10 per cent plus 100 mesh, the discharge may be only 5 per cent plus 100 mesh at first. With twice as much inflow as outflow of 100-mesh material, it will concentrate in the Agitator while gradually increasing in the outflow until an equilibrium may be reached in which the feed and discharge will both be 10 per cent and the average pulp in the tank 20 per cent, so that the exposure of coarse sand would be approximately double the average. While this is theoretical, enough work had been done to indicate that the idea can be put to practical use.

Dorr Agitators have been installed in tanks of various sizes, the largest being those in use at the Desert Mill at Tonopah, Nevada, in tanks 36 feet in diameter by 20 feet deep. The Company estimate that the total power required to operate one of these large machines, including mechanical horse-power and the air required for maintaining agitation, is not over 5 H.P., so you will see that it is extremely small. A recent measurement in a 20 by 12 foot Agitator showed that 10 cubic feet of free air at 15 lbs. pressure was all that was needed. The application of Dorr Agitators in the chemical industry has not been investigated to any extent, but it would seem that with finely divided materials from which it is desired to dissolve one constituent that they should perform as useful a function as they are now doing in metallurgy.

Acid-proof Machinery

As all submerged portions of Classifiers, Thickeners, and Agitators have no reciprocal motion, it has not been found difficult to manufacture them so as to resist ordinary acid liquors, and acid-proof machines of all three kinds are now regularly built and in use.

STUDIES ON FILTRATION

By J. W. BAIN and A. E. WIGLE

Read at the Troy Meeting, June 17, 1914

In connection with factory operation quite recently, one of the authors had to form an estimate, in advance, of the amount of moisture which would be retained by a finely divided solid on a vacuum filter. A search among the usual sources of information yielded no serviceable data. When the filters were in actual operation, their performance in this respect was very much better than had been anticipated, and had this fact been known in advance, some economy in construction might have been effected.

With a view to gaining information on this point, the authors investigated the literature at their disposal, and with the exception of the interesting and valuable paper by Hatschek,[1] they were unable to find any useful data. When the experimental work had progressed to a certain extent, an accident drew our attention to the exhaustive monograph of King and Slichter, "Principles and Conditions of the Movements of Ground Waters,"[2] from which we have drawn freely in this discussion.

In the problem which is here under investigation, the solid is assumed to be bathed by a liquid in which it is insoluble, such as, for instance, the mother liquid of a crystalline magma. It is proposed, therefore, to investigate the amount of liquid retained by a mass of finely divided solid when filtration is carried out under atmospheric or other pressure and also in the centrifuge.

The experimental work was considerably simplified by the condition laid down above, which permitted the use of a solid insoluble in water. A quantity of pure well-rounded lake sand was carefully sieved, and the grains which were retained on the 40 mesh screen, but which passed the 30 mesh, are referred to throughout as 40 mesh sand. The screens used were not of very good quality in the regular-

[1] *J. Soc. Chem. Ind.*, 1908, p. 538.

[2] Nineteenth Ann. Report, U. S. Geological Survey.

ity of the mesh opening, as will be seen from the data given later, but this point is of no particular significance in this investigation.

The rate of flow of a given liquid under a constant head through a filter-mass of a finely divided solid will obviously be dependent upon the amount of space which is not occupied by the grains, i. e., what is commonly called the "pore space." On first consideration, it would appear that the pore space would vary a good deal according to the size of the grains composing the mass, and the results of computation and experiment are an astonishing contradiction to this idea. The pore space is almost independent of the size of the grains, and the arrangement of the latter is of chief importance. By considering a number of small spheres of uniform diameter packed as closely as possible in a given space, it is possible to arrive at a mathematical formula from which the pore space may readily be calculated.

Slichter[1] has shown that if the spheres are so arranged that their centers lie at the corners of a cube, the pore space will be 47.64 per cent; while if the centers of the spheres lie at the corners of a rhombohedron which permits the closest possible packing, the pore space is 25.95 per cent. Between these limits we may expect to find the porosities of all ordinary materials.

With actual materials, in the case where the grains are of approximately equal size, the pore space and also the diameter of the particles may be readily determined by counting a number of the grains, determining their combined weight and the specific gravity of the material; the total volume may be ascertained by adding the sand in small quantities to a cylinder, tapping gently with a flat-faced pestle until no further decrease in volume takes place. The results of this procedure on our sands are presented in Table I.

The comparatively slight variation in pore space is worthy of note; and it may be added at this point that mixtures of small and large grains show a surprising similarity in their porosity to that of either taken alone. For all practical purposes, the pore space of masses of crystals, such as are commonly produced by rapid cooling, may be placed at 37 per cent of the total volume occupied.

Filtration Under Atmospheric Pressure—This part of the subject has been so carefully worked out by King[2] that it suffices to reproduce some of the results, slightly modified to suit the present purpose. Cylinders 8 feet long, 5 inches in diameter, were filled

[1] Loc. cit., p. 309. [2] Loc. cit.

with special, sorted sands, wire gauze being used as a support at the bottom. Water was introduced from below, and when the tubes were full, percolation was allowed to commence, and the water which drained away was collected and weighed at intervals.

TABLE I

Mesh Screen.	No. of Grains.	Total. Wt, Grms.	One grain grm. $\times 10^{-5}$.	Sp. Gravity.	Pore Space Per Cent.	Diam. Mm.
30	300	0.0307	10.23	2.74	35.4	0.420
	300	0.0316	10.36			
40	400	0.0251	6.3	2.68	34.1	0.354
	400	0.0253	6.3			
50	400	0.0182	4.55	2.73	36.4	0.318
	500	0.0246	4.92			
60	800	0.0238	2.97	2.82	36.8	0.269
	600	0.0172	2.87			
80	800	0.0202	2.52	2.85	37.7	0.257
	600	0.0156	2.60			

TABLE II

Effective Size of grains, Mm.	Pore Space, Per Cent.	Water Retained—Per Cent of Dry Sand.	
		After 1 Hour.	After 9 Days.
0.4745	38.86	11.23	4.24
0.1848	40.06	12.72	5.05
0.1551	40.76	14.73	7.25
0.1183	40.57	19.30	9.41
0.0826	39.77	20.15	11.82

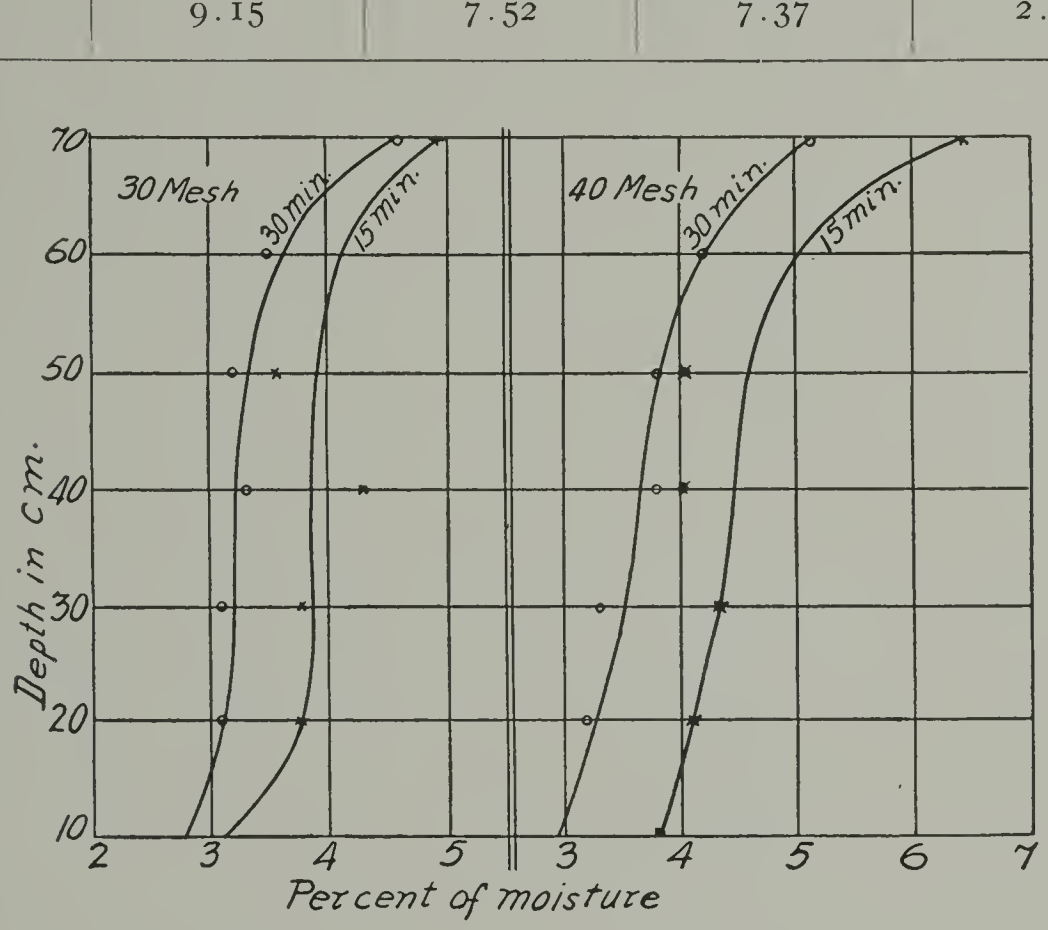
FILTRATION WITH VACUUM—Experiments were carried out by the authors with the idea of approximating to factory conditions.

The sand was poured into a Buchner funnel provided with a piece of wire gauze, and gently tamped down with a flat-faced pestle; the depth of the layer was 1¼ inches. The top of the funnel was closed by a glass plate ground to fit and provided with a central aperture through which air could be admitted. To avoid the error of surface evaporation during filtration, this air was drawn through a tower, down which water trickled slowly. The funnel was placed in a suction flask, and a simple gauge enabled the vacuum to be read. When the sand had been under vacuum for a given period, it was thoroughly mixed and a sample removed; water was once more

poured on and the vacuum was maintained for a longer period. The results are given in Table III.

TABLE III

Mesh Screen.	Moisture at the End of			Vacuum Ins. Mercury.
	5 min.	15 Min.	30 Min.	
30	7.20	5.69	4.75	1.5
40	8.20	6.84	5.19	1.75
50	8.65	7.50	6.41	0.75
60	8.42	7.38	6.90	2.0
80	9.15	7.52	7.37	2.25



It is seen from these results that the moisture content increases inversely as the diameter of the grains of sand. In each experiment the water pump was worked at full capacity, and as might be predicted, the vacuum increases slightly as the size of the grains decreases.

By way of comparison, a single experiment with sand of mesh 50 may be quoted. Water was poured on the layer and no vacuum was used; after 15 minutes' standing, the moisture content was found to be 27.4 per cent against the 7.50 per cent under vacuum.

The amount of liquid retained by different portions of a mass of grains in a filter, becomes important when the question of washing

away an impure mother liquor has to be considered. A series of experiments was performed with the object of ascertaining the amount of water retained in the sands at different levels while under vacuum.

To carry this out, a tube about 80 cm. long and provided with side tubes closed with corks at 10 cm. intervals, was filled with each sand, and connected as has been described in the case of the Buchner funnel. A powerful water pump was run to full capacity and the pressure, as before, varied with the size of the grain. The results are given in Tables IV and V.

TABLE IV

PERCENTAGE OF MOISTURE AT THE END OF 15 MINUTES

Mesh Screen.	Pressure Ins. Mercury.	Depth of Sample from Top in Cm.							Mean Per Cent Moisture.
		10	20	30	40	50	60	70	
30	4.5	3.13	3.78	3.77	4.28	3.56	4.13	4.90	3.97
40	4.0	3.82	4.10	4.33	4.08	4.08	5.08	6.45	4.60
50	6.5	3.90	4.40	5.00	4.80	5.30	5.60	7.60	5.30
60	7.0	4.14	4.95	5.32	5.20	5.20	5.63	6.60	5.30

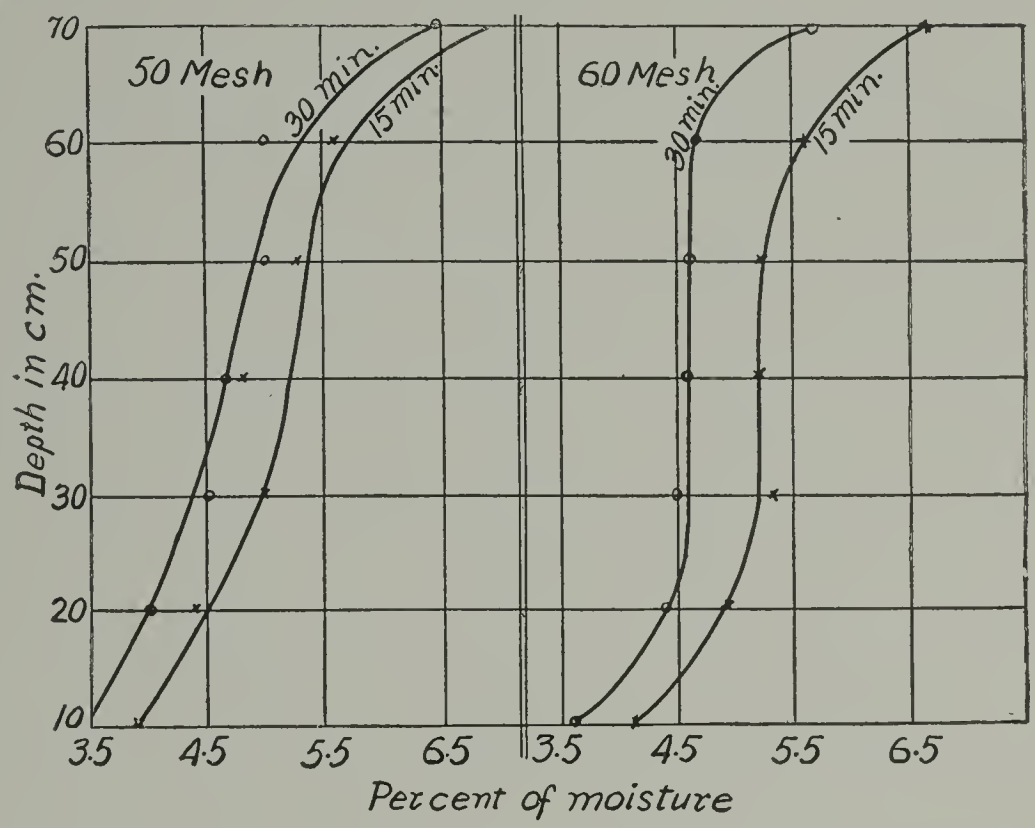
TABLE V

PERCENTAGE MOISTURE AT END OF 30 MINUTES

30	4.5	2.84	3.08	3.10	3.31	3.19	3.51	4.56	3.35
40	5.0	3.03	3.24	3.30	3.76	3.83	4.20	5.13	3.85
50	6.5	3.40	4.00	4.50	4.65	4.95	5.00	6.50	4.70
60	7.0	3.58	4.37	4.56	4.60	4.60	4.65	5.75	4.70

These results were plotted and curves were drawn as shown in the accompanying illustrations. The individual points were sometimes decidedly off the curves, but although the experiments were repeated in these cases, no better agreement could be obtained; the accurate determination of small amounts of moisture in these sands proved to be difficult, probably owing to sampling. The average per cent of moisture was determined by measuring the areas under the curve, and dividing this by the height which gave the width of the rectangle of equal area.

FILTRATION WITH CENTRIFUGE—This well-known method of separating solids from liquids was next subjected to test for the sake of comparison with the previous experiments.



A small hand centrifugal, 4¼ inches inside diameter, was used; it could be run at 5000 R.P.M. without any trouble. A cylinder of wire gauze, 1¾ inches in diameter, was placed over the axis of the machine and the sand was poured into the annular space thus formed; the layer had, therefore, a thickness of 1¼ inches, which was the same as that in the Buchner funnel.

As a preliminary experiment, the sand was thoroughly wetted, and the centrifugal run at 2000 R.P.M. for 2 minutes. The percentages of moisture are given in Table VI.

TABLE VI

PERCENTAGES OF MOISTURE

Mesh Screen.	Vacuum 15 Min.	Centrifugal 2 Min.
50	7.50	2.56
60	7.38	2.55

The marked efficiency of the centrifugal is noteworthy and the method of precedure was altered to show this more forcibly.

Sand was placed in the Buchner funnel, wetted and vacuum applied for 5 minutes. After sampling, the sand was placed while still moist, in the centrifugal, which was then run for 2 minutes at 2000 R.P.M. Table VII shows the percentages of moisture.

TABLE VII

PERCENTAGES OF MOISTURE

Mesh Screen.	Vacuum 5 Min.	Centrifugal 2 Min.
30	7.25	2.26
	7.12	2.20
40	7.50	1.93
	7.60	2.30
50	8.70	2.56
	8.60	2.80
60	9.35	2.36
	8.40	2.65
80	9.70	2.49
	9.56	2.46

It is seen from the above results, that the moisture content under vacuum varies inversely as the diameter of the grains; the moisture content after centrifuging, however, is nearly the same for the finer as it is for the coarser sands.

The distribution of the water at several points in the annulus of sand was also investigated and Table VIII presents the results in percentage of moisture.

TABLE VIII

PERCENTAGE OF MOISTURE

Mesh Screen.	Distance from Center of Basket		
	½ Inch.	1 Inch.	1½ Inch.
40	2.9	2.72	2.43
50	3.0	2.90	2.76

The variation, while sufficient to permit measurement, is small and might be neglected for practical purposes.

The objection may be raised that these results, obtained in the laboratory with a small centrifugal, are of little value for comparison

with the larger machines used in the factory. While with the hand centrifugal, the diameter is small, the speed is high, and we have calculated that a weight of 1 lb. revolving at a 2 inch radius at 2000 R.P.M. is subjected to practically the same centrifugal force as a weight of 1 lb. revolving at a radius of 12 inches at 600 R.P.M. The comparison is, therefore, justifiable and a good idea of the behavior of a moist mass when centrifuged in the factory, may be obtained beforehand in the laboratory.

Using the formula given by Griscom,[1] we have calculated the pressure at the periphery of the 4¼ inch centrifugal running at 2000 R.P.M. and find it to be 7.66 lbs. per sq. in.

Theoretical Consideration—Hatschek[2] has discussed the behavior of very finely divided substances on the filter, and has pointed out the value of a microscopic examination in this connection. The probable arrangement of the particles, with respect to the pores of the septum, are pointed out, and the influence of the flexibility of the latter is taken into consideration.

The retention of small quantities of liquid in the mass of fine grains is due, undoubtedly, to capillarity. The extraordinary difficulty in removing the last few per cent is well known and is again set forth above. In considering the reasons for this, it seemed to be worth while to calculate what would be the thickness of the film, if all the residual water were assumed to be distributed uniformly over the superficies of the grains. For this purpose, sand of 30 mesh with 6 per cent moisture was selected; the thickness of the film of water on each grain was found to be 0.0116 mm.

It would be interesting to calculate what stress must be applied to a grain thus coated, to overcome the surface tension of the liquid in so far as to allow the removal of at least part of the water; such a computation, if it could be effected, might furnish a scientific basis for the prediction of the behavior of finely divided solids on centrifuging. The authors have been unable to find time to carry this out, but hope to do so in the future.

The above discussion assumes that all the water is present on the superficies of the grains, but the capillary action of the small spaces between the grains is undoubtedly of great importance. In the case of the sand just quoted, which has a pore space of 35.4 per cent, the moisture present would fill 30 per cent of this; that is, 70 per cent of the pore space is filled only with air. This gives some idea

[1] *Metal and Chem. Eng.*, April, 1913. [2] Loc. cit.

of the comparatively poor performance of the ordinary filter and of the vacuum filter; in each case, air channels form and the downward pressure on the water-filled pores is thus relieved. In the case of the centrifugal, each particle of water experiences practically the same stress, and only the capillarity of the finest pores and the surface tension of the films on the grains are sufficient to resist its action.

Summary

1. The pore space in a mass of fine grains averages about 37 per cent of the total volume.

2. The amount of water retained when an ordinary filter is used varies from 11 per cent, with 20 mesh material, to 20 per cent with 100 mesh material, one hour being allowed for drainage.

3. The amount of water retained on a filter with 2 in. vacuum averages 7 per cent after 15 minutes for material varying from 30 to 80 mesh.

4. In a layer of material 70 cm. deep on a filter, with 5 in. vacuum, the top layer will average, after 15 minutes, 4 per cent moisture, and the bottom 6.5 per cent; the size of the grains is not of importance within the limits discussed. If the vacuum be maintained for 15 minutes longer, the above figures will be reduced by another half per cent.

5. By the use of a centrifugal, the percentage of moisture, in all the materials employed, may be reduced to an average of 2.5 per cent.

6. In the case of a sand of 30 mesh with 6 per cent moisture, if all the water be distributed over the surface of the particles, each grain would have a film 0.0116 mm. thick; or the water would fill 30 per cent of the pore space.

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SCRUBBER FOR CHEMICAL LABORATORY VACUUM SYSTEM

By CHARLES BASKERVILE

Read at the Troy Meeting, June 17, 1914

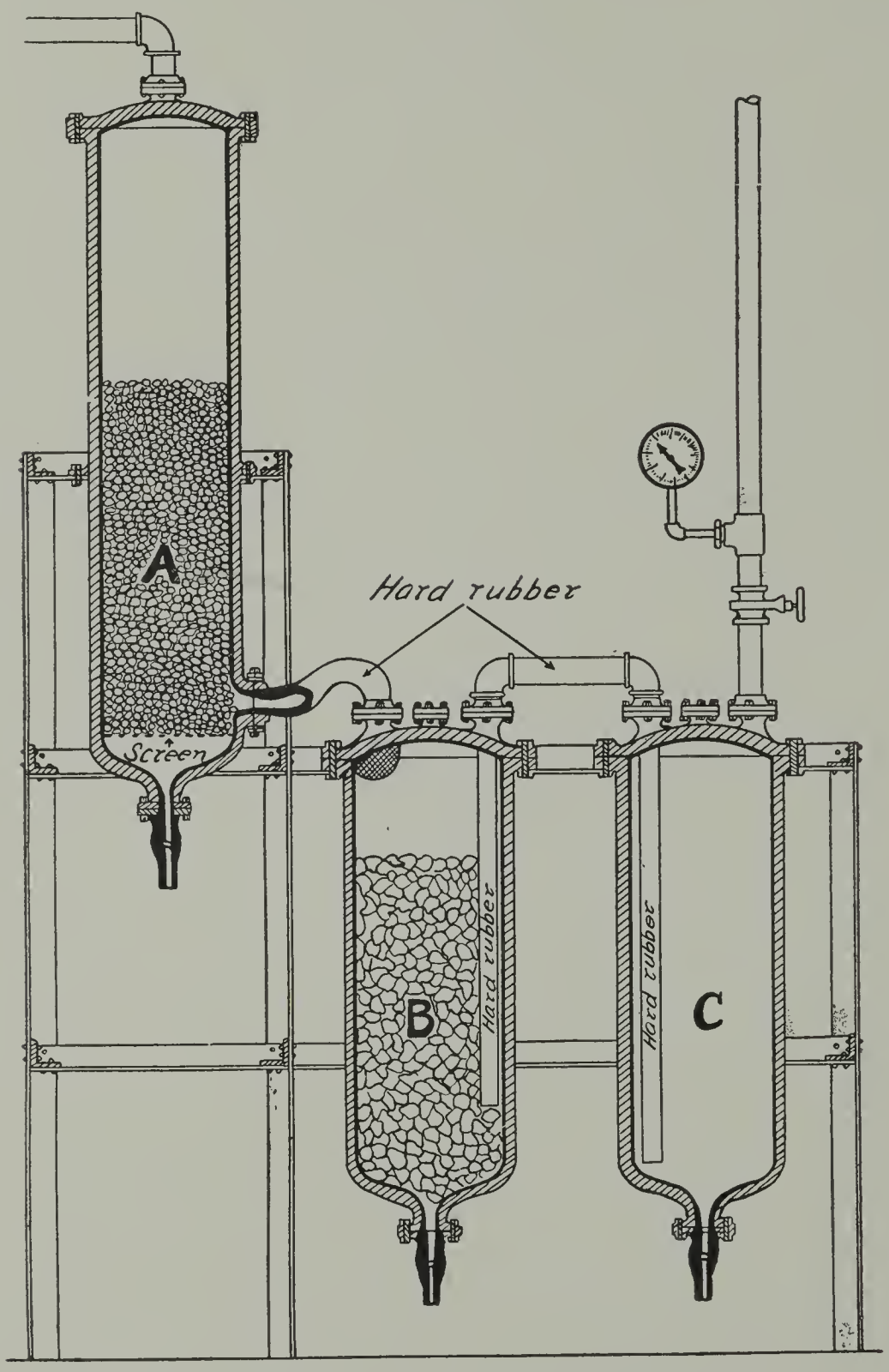
In order to protect the vacuum pump of our laboratory from the corrosive action of the gases drawn therein, I devised the installation described herewith. The pump—an improved Packard Vacuum Pump, 2 cylinder, 12 in. diam., motor-belt driven—has been in more or less continuous service for seven years without any expenditure thereon for repairs, as a result of this protection. It seemed safe, therefore, to present an account of it.

The installation is an application of the simple principles usually applied on a small scale with glass apparatus in the laboratory.

The towers are made of cast iron, porcelain-lined, and set into the system with a by-pass, which we have used only during the short time necessary for recharging. The towers are connected by hard rubber pipes (2 in. internal diameter). At the bottom of each tower is a hard rubber drain cock, bolted to a flange. At the top of *B* and *C* are plates bolted to flanges which may easily be removed. The opening is of sufficient size to admit dropping a strung incandescent bulb for inspection.

Tower *B* is three-quarters filled with pumice stone in egg-size pieces. The pumice is thoroughly saturated with concentrated sulfuric acid. I believe lead pipe would be better in this cylinder, as the hard rubber softened on contact with the acid. So far, however, the weight of the pumice and acid has not been sufficient to cause the hard rubber pipe to collapse. The decomposition of the rubber compound became so pronounced with the drain cock in a short while that it was replaced by a lead plate, which has proven satisfactory. Incidentally, it may be stated that all efforts to get the hard rubber people to provide a material which would stand up against cold concentrated sulfuric acid have been futile. Hence, it may be well to warn others as to their claims in this respect. A

pear-shaped screen of copper gauze was placed in the opening of Tower *B* leading to Tower *A* to prevent clogging, in the event a rushing action of the pump sucked pieces of the pumice. We draw off and replenish the acid once or twice a year.



Scrubber for Chemical Laboratory Vacuum System—Scale, 1 in. = 2 Ft.
A—Caustic Soda; B—Sulphuric Acid and Pumice; C—Trap.

Tower *A* is half filled with angular pieces of commercial caustic soda, in size from a hazel nut to an egg. The mass rests upon a copper wire gauze screen supported on and by the tapering bottom of

the tower. The drain cock admits of drawing off any liquefied caustic which may accumulate. A metal pipe leads from the top to the pump.

Tower *C* is a safety reservoir to catch the fluid from *B* in the event of a leak beyond or other cause for increase in pressure on the pump side in the line. So far, no indication of its real need has been apparent, as the maximum and minimum contacts of the automatic regulator of the motor have never failed.

A gauge in the system beyond the scrubber serves, by comparison with the gauge on the pump, to show leaks in the scrubber. None was observed until the hard rubber drain cock on Tower *B* failed, and none has been noted since the change described above, over six years ago.

The whole installation is supported on angle iron, painted with a rust-proof paint, and may be inspected by members of the Institute any time.

College of the City of New York.

SHODDY AND CARBONIZED WASTE

By LOUIS JOSEPH MÁOTS

Read at the Troy Meeting, June 17, 1914

For many years there has existed a small though important industry that is devoted entirely to the working up of rags of all kinds, and of woolen waste, recovering from it the wool fiber and putting it in condition so that it can be re-used to advantage. This is the "shoddy" industry, and though somewhat prosaic, and out of the usual order of technical papers of interest to the Institute, is in a great measure dependent for its progress upon the combined skill of both engineers and chemists.

There have been proposed from time to time numerous processes for the destruction and removal of vegetable particles from wool in all stages of manufacture. Burrs, seeds and other plant fragments are found normally in most all raw wools. Fine particles of cotton or other threads occasionally, though accidentally, are picked up during the travels of pure wool through the mill; these show distinctly in piece-dyed goods when finished and call for the process of "speck dyeing" and in the better grade fabrics for "carbonizing in the piece," and finally the process of rag carbonizing which forms the basis of this paper.

The importance of this industry may be appreciated when it is realized that if all the wool clipped during any one year be converted into cloth suitable for garments and equally distributed among the inhabitants of the temperate or wool wearing zones, there would be but fourteen (14) ounces of cloth to each individual, sufficient to make only a single pair of knee breeches per person. Consequently, in order to provide a sufficient supply, wool must be obtained from another source, and this source is, of necessity, previously made and used woolen cloth in the form of rags.

The various kinds of stock that serve as raw material for the manufacture of shoddy and similar products are subject to several classifications based upon whether the rags are "new," that is, rags

and clippings obtained from clothing manufacturing establishments, etc.; "old stock" or rags obtained from previously worn clothing; and "wool waste" which, as its name indicates, may be regarded as the waste sweepings from woolen mills. These groups are classified about as follows:

NEW—CLIPS. Clips, factory wool, fine mixed, fine merchants tailor, coarse gray, ordinary light, fine dark. *Worsteds:* choice light, fine gray, fine dark, black, blue, brown. *Serges:* brown, blue, black, light, dark, light fancies, dark fancies. *Worsted edges:* blue, black. *Flannels:* new blue, new scarlet. *Plain black kerseys. Unions:* new, dark, ordinary. *Mixed cloakings.*

OLD STOCK—*Soft woolens:* best, coarse. *Red flannels:* white softs. *Merinos:* fine light, fine dark, coarse dark, fine black, soft woolens. *Old blue flannels:* thibets. *Serge:* black, brown, green, small skirted, blue skirted. *Knit stock:* white, light gray underwear, coarse gray, steel gray. *Cloth,* rough, tan, fine brown, coarse brown, skirted, small, dark, black, light blue, mixed. *Worsted:* light, blue, black, dark. *Carpet. Soft flannel. Satinet garments:* mixed satinets. *Seams:* mixed, delaine, skirted.

WOOL WASTE—Colors, strictly all wool delaine, extract, dark, light, black, blue, brown and fancy colors. Black serge, blue serge. Ring waste, fine foreign, fine domestic, coarse foreign, domestic. Noils, fine ½ blood, ⅜ blood, ¼ blood, French combed; carpet. Hard ends, white worsted, colored worsted. Yarn waste, colored (all wool) woolen, white (woolen), colored (woolen), colored (cotton mixed), white carpet. Card waste, ¼ blood, ⅜ blood, white woolen, colored. Burr waste, white colored. Pill stock, white.

The operations necessary to convert apparently useless rags into a merchantable and useful fiber, requires that they be subjected to the action of disintegrating machines termed pickers and garnets, which pull the rags apart and break them up more by a tearing and shredding operation than by cutting, followed by a succession of garnet machines of increasing fineness whereby the threads that composed the original rags are unraveled into their constituent fibers. Under the broad term "regenerated wool" is to be included all those forms of wool that have been recovered from rags and cloth clippings.

When this disintegrating operation is carried out with soft rags or rags of unfulled woolen fabrics, such as knit-goods, flannels, shawls, etc., and the waste incident to their manufacture, the result is termed "shoddy," the fibers being relatively long, averaging from

2/5 to 1 1/4 inches. On the other hand, where the rags are from originally heavily fulled woolen fabrics or other classes of hard rags, the resulting fiber is termed "mungo," conveying the impression that the stock is short, due to the breaking of the fiber during the disintegrating. The length of "mungo" fiber varies from 1/5 to 3/4 of an inch. It is rarely used alone for yarns, but generally with new wool or cotton. It is further distinguished by being incapable of fulling. Extract wool, or commonly, "extract," is a regenerated wool fiber that has been freed from vegetable matters.

As is apparent, there must be present in the rags at times, certain varying amounts of cotton threads, or admixed cotton, the former due to the stitching of seams, etc., while the latter is due to cotton in the cloth in the form of warp threads, or loose cotton mixed with wool to make the so-called "merino" yarn. Consequently, in the "manufacture" of regenerated wool, it is necessary to make use of some chemical process that will destroy the cotton present in the rags, without appreciable chemical action on the wool. This process is called "carbonizing" and the regenerated wool fiber obtained is called "carbonized stock" or "extract."

The carbonizing process dates from 1851, and is the reverse of the well-known reaction of caustic alkali on mixtures of wool and cotton, whereby the wool is dissolved, leaving the cotton intact. It is recorded that a certain Captain Corbett, visiting the London Exposition in 1851, was attracted by the caustic boiling process as applied to treating cotton rags for the purpose of freeing them of wool fibers, thereby fitting them better for the use of the paper maker. However, he regarded wool as being the more valuable fiber to recover, and devised the process of treating woolen rags with weak acid to destroy the cotton. He started an extract plant at Mitcham, in Surrey, but his output attracted little attention in Yorkshire, as the local makers of woolens realized at once that the fibers would not "felt" or "full" properly, as they had lost their milling qualities.

Notwithstanding the work of Corbett, it is a fact that Kober, a German, and Isard and Leloup, Frenchmen, publicly used the acid carbonizing process about 1854 in their respective countries, since which time there have been introduced, by various inventors, between thirty and forty modifications, involving chiefly mechanical appliances, and it is curious to note that all the methods actually referred to in these modifications have been based upon the use of an acid reaction.

The chemical reaction forming the basis of the carbonizing process is very simple, and is as follows:

$$C_6H_{10}O_5 = 5H_2O + 6C.$$

The chief results aimed at by the shoddy carbonizer are governed by the following conditions, based upon many trials made with cotton in the presence of wool, and under varying conditions. At 140° to 145° F. the cotton becomes brittle, and it is in this condition that the shoddy maker desires to have it. When the temperature is maintained at about 145° F., there is little or no danger of the acid injuring the wool. Between 150° and 160° F. the cotton fiber browns distinctly, but an incipient injury is done to the wool. Between 165° and 170° F. the cotton is actually charred. Therefore, using acid of from 2 to 3 per cent strength, and baking at a temperature of 140° F., the cotton is converted to a condition easily removable in the willowing machine without any action on the wool.

The most commonly employed process for rag treatment consists of immersing the rags in huge tanks containing a weak solution of sulphuric acid, generally ranging in strength from 2 to 4 per cent. After soaking for several hours, the rags are removed from the tank and drained, and the excess of acid is removed by means of a centrifugal, and returned to the tank for further use. The rags are then put through a drying oven and baked, keeping the temperature about 145° F. so that the cotton or other vegetable fiber present is completely destroyed. As many of the rags subjected to this process are previously dyed, the action of the combined acid and high temperature is in some instances likely to affect the colors, which causes the resulting "shoddy" to fall into its own particular commercial class as to colors. On the other hand, the manufacturer of shoddy and extracts is often called upon by the woolen manufacturer to supply a particular grade of shoddy dyed a special shade and to possess certain properties, such, for instance, as fastness to severe milling, and in consequence, the shoddy dyer must use the same kind of dyes that the dyer of the pure scoured wool must employ when equally high standards are set.

In cases where the color on the original rags is not suitable, the shoddy manufacturer must remove or reduce it to such a point that they can be re-dyed to match the given shade. This color-removal process is called "stripping," and is accomplished by means

of: (1) soda; (2) bichromate of potash, sulfuric acid and oxalic acid; or (3) with hyraldite for stripping—a zinc-formic-sulfite compound—which chemically destroys many of the dyes used for wool. These several processes are used according to the nature of the original dye on the rags.

Stripping with Soda—The rags are treated for not less than half an hour at 120° F. with a solution of 5 to 10 per cent of soda ash, calculated on the weight of the rags, and followed by a good rinse. Soda stripping is usually adopted for colored rags, fragments of women's dresses, etc., as they are dyed chiefly with acid colors.

Stripping with Bichromate of Potash, Sulphuric Acid, and Oxalic Acid—All material that is not sufficiently stripped by the first process should be subjected to this process. Indigo and wood colors especially are stripped by this treatment, and alizarine colors are sometimes converted into shades that are more easily over-dyed. The rags are boiled for ½ to ¾ hour with 3 to 6 per cent of bichromate of potash, 6 to 12 per cent sulphuric acid, and 3 to 6 per cent of oxalic acid. They are then rinsed and carbonized.

Stripping with Hyraldite—Hyraldite is now largely used in the stripping of shoddy. It does not affect the fiber in the least. It destroys most acid colors as well as a great many chrome colors, so that very light-colored goods may be produced from very dark or even black material. Stock stripped with hyraldite does not have a tendency to turn a yellowish tint afterwards, as is usual with other stripping methods; this is an advantage when subsequently dyeing shades of blue, violet, green and other light mode shades. The stripping is done at a temperature of 120° F., with from 2 to 4 per cent of hyraldite for stripping, 2½ to 5½ per cent of formic acid, afterwards raising to the boil, and working for ½ hour, followed by a rinse.

Another carbonizing process that is largely used, is based upon the destructive action of gaseous hydrochloric acid generated either by allowing the liquid acid to flow slowly into an externally heated iron chamber, or by heating a mixture of rock salt and sulphuric acid. The hydrochloric acid or dry gas process, in several modifications, has been patented by a number of inventors, the two most important patents being issued to Messrs. Jourdin & Balan, in 1877, and the other to an inventor named Michel, in the same year.

Nitric acid in gaseous form has also been used, the gas being generated by the action of sulfuric acid upon nitrate of soda, but

the result was not a success; while the cotton or other vegetable matter was destroyed, the wool fiber was considerably injured.

Certain metallic salts have been recommended from time to time, but those most commonly used have been chloride of aluminum and chloride of magnesium. The former is usually employed in solution of a strength between 9° and 10° Tw. The material to be treated is saturated by soaking for a few hours, afterwards whizzed and dried at a moderate temperature, and finally baked in the carbonizing oven at 194° F. for an hour. Usually the vegetable matter becomes very brittle and easily dusted out before this temperature is reached. Afterwards the stock is well washed. This process is less injurious to the wool than the acid process, but it is more costly. It is believed by the writer to be properly credited to Joly, of Elbeuf, France, who referred to its use particularly in carbonizing fabrics. Magnesium chloride, while destroying vegetable matter, is not as easy to handle as aluminum chloride.

There are other processes for carbonizing rags, which may be mentioned as follows: Calcium chloride in solution, recommended by Poulin, of Paris, in 1881, who used 4 parts of a solution of the calcium salt at 32° Tw. diluted with 3 parts of water. Another solution consists of 2 parts of sodium chloride and 2 parts of hydrochloric acid in 10 parts of water. Both of these solutions destroy cotton fiber, but offer no advantages over the usual processes. Since the extended use of silk for sewing and for fancy effect strips, etc., as in the manufacture of men's and women's goods, there are immense quantities of shoddy on the market that are unavailable on account of the particles that cannot be successfully removed by any practical carbonizing process. It is a fact that silk is dissolved in a solution of ammonium-copper-oxide (Schweitzer's reagent) and without action on the wool, but while excellent results are obtained by treating small batches of shoddy with this reagent, difficulties are met that prevent its use on a commercial scale.

The handling of rags on an industrial scale has remained a thoroughly organized business, which, in the metropolitan centers is more completely specialized than in the smaller places, but the operations generally work out in the following order:

1—Rag gatherer, or rag man
2—Local rag dealer.
3—Central rag dealer.
4—Rag sorter, or shoddy dealer.
5—Shoddy manufacturer.
6—Woolen mill.

A mill for the utilization of shoddy, or its conversion into finished fabrics, does not differ materially from an ordinary woolen mill; the sequence of operations being in the following order, and as described, contemplate the plant commencing its operations with sorted rags as bought from the rag dealer:

1—Rag shaking: object—the removal of dirt, dust, etc.
2—Extracting or carbonizing.
3—Stripping according to the nature of the rag: object—the removal of the old dye. This operation is sometimes omitted where the original color of the rags will serve as such in the cloth contemplated.
4—Dyeing.
5—Drying and oiling.
6—Garnetting.
7—Blending and oiling.
8—Teasing.
9—Carding.
10—Spinning.
11—Weaving.
12—Scouring, to remove the added oils.

For some classes of cloth the fabric is dyed after scouring, and when this is done, the dyeing operation No. 4, above, is omitted.

13—Raising and milling.
14—Finishing.

The shoddy of commerce is graded as follows: Fine white wool yarn, worsted yarn. Garnetted white shoddy, all wool. Medium white knit shoddy, all wool. New fine black worsted shoddy; medium black worsted shoddy; new blue worsted shoddy, best fine. Dark mixed yarn shoddies, extra fine and free from cotton; light yarn shoddy, extra fine; light yarn worsted; dark mixed; fine thibet, all wool; fine dark merino, No. 1 all wool. Medium dark merino, all wool; coarse dark merino, all wool; fine light merino. Coarse light merino. Medium light, not all wool. Red knit shoddy, all wool. Dark blue shoddy for hosiery manufacturers, strictly all wool; and the same not all wool.

From the above it is seen that certain gradings depend upon colors, and in a large number of instances, the color of the finished shoddy is that of the rags from which it is made.

The dyeing of the shoddy rags to meet special demands of mills, is almost invariably done after stripping and carbonizing, since the small amount of acid remaining in the carbonized rags and not washed out aids in the dyeing.

Rag dyeing is done in either a very crude or in a most advanced way. It is either done in huge dye-tubes where the rags are poled about by hand, or else in pressure dyeing machines where the rags are packed in fixed dye-chambers and the dye liquor made to circulate through the fixed mass.

Certain of these dyeing machines have been constructed of immense size so as to handle a large quantity of rags at one time, which is quite necessary, owing to the average low intrinsic value of the material. Such dyeing machines have been built with double cages, one in service with a charge of 1000 pounds of rags, while the other cage is being emptied and refilled. One such machine is sufficient to keep a fair-sized shoddy mill constantly supplied with dyed rags. It is usual, however, to have one or two supplementary machines of smaller size either in reserve, or for taking care of special small dyeings.

Other types of rag dyeing machines are constructed on the horizontal revolving perforated cylinder form, in a fixed volume of dye liquor. In either case the result is practically the same.

Woolen rags—or extracted rags, that have been stripped and are to be dyed, must be so dyed as to stand the usual milling treatment that is given to the cloth of which it forms a part. Few cloths are made wholly of shoddy: varying percentages of new wool must always be used, or great difficulty will be experienced in spinning the threads.

For the production of dyeings very fast to milling the anthracene colors are used in the first place, and some acid colors which are especially fast to milling, such as milling yellow, milling red, wool red, formyl violet, formyl blue brilliant milling blue, tetra cyanole A, alphanol blue, brilliant milling green, anthracite black and alphanol black. Numerous diamine colors are also entirely fast to milling next to wool; and some of this group, as for instance, diamine fast red F, diamine green G, diamine brown R, M and B, diamine catechine G and 3 G, diamine fast gray B N, may, by an after-treatment with bichrome or chromium fluoride, be fixed so completely as to possess very good fastness to milling even next to white cotton.

The usefulness of shoddy cannot be doubted; it occupies a most important position in the manufacture of many lines of woolen textiles sold at prices that could not be otherwise produced, for reasons previously indicated.

As to the pending legislative attempt to impose upon manufac-

turers the necessity of branding their goods, indicating the presence and amount of shoddy used, I do not propose to venture an opinion. In view of the fact that no known method exists whereby chemists or microscopists can definitely state whether a given fabric consists wholly or partly of shoddy, it is impossible to ascertain the amount contained in any fabric, although many attempts have been made from time to time to devise a practical method for determining its actual presence in fabrics, but without successful results.

It seems that the only way to accurately control the admixture of shoddy or regenerated wool fiber or other textile adulterant, so that the ultimate buyer of cloth could be assured as to what he is buying, would be to provide for the installation of some federal official in the mill, as is done in matters connected with the manufacture of fabrics for the Army, or in the animal products inspection service, and coupled with the final official branding of the finished article.

While the shoddy industry is small, it is essentially one that the chemical engineer can investigate with profit. It has been struggling along for many years without attracting a particle of scientific attention, and as a consequence has remained practically stationary except for a few very minor improvements to some of the machines employed. The carbonizing process alone offers a promising field for investigation and particularly in view of the constantly increasing prevalence of *silk* particles in rags, the presence of which offer distinct obstacles in cloth manufacturing, as many of the dyes used color the wool satisfactorily, but leave the silk only partially stained.

In conclusion, permit me to venture the assertion that the shoddy manufacturers are entitled to great respect and encouragement as belonging to the increasing army of conservationists so much needed in a new and fast-growing country. The motto of the great Franklin: "A penny saved is a penny earned" might well be their shibboleth as making clear their right to the encouragement and coöperation of all economic factors.

103 North Nineteenth St.,
East Orange, N. J.

DISCUSSION

PRESIDENT: The paper is now open for discussion.

Mr. O'NEIL: Is there any difference in the quality of shoddy between old and new wool?

Dr. MATOS: Shoddy wool is pure wool. Some grades of shoddy sell, however, at a higher price than some grades of new wool.

Dr. OLSEN: Is there any cloth manufactured without the addition of shoddy?

Dr. PALMER: A great deal.

Dr. MATOS: Dr. Olsen has raised a delicate question. There is hardly a woolen mill but what uses shoddy in some form. It is a fact that there are many grades of cloth on the market beautifully finished, which, upon careful examination are found to contain considerable cotton. This cotton is not "shoddy," but is to be regarded rather as an adulterant, and taking the place of new wool or regenerated wool. There is a concern in this country that supplies the highest grades of cotton for use in the manufacture of woolen fabric.

Dr. PALMER: I want to say there are some high grades of wool fabrics made from the original wool fiber without any shoddy in them. If you are willing to pay from $2.50 to $3 a yard, inside price, you can get a pretty good article. I know a friend that has an overcoat that he has worn seven or eight years and it looks as though worn only six months. I know the government goods are made from good material. The meaning of the word "mungo" is thus explained. A few years ago a shoddy manufacturer in England found that his stock was sinking lower and lower and by and by he didn't know whether he should buy more shoddy or not. The manufacturer went down and told his foreman "it mungo" meaning in provincial English, "it must go." It is a very good description of a low grade shoddy.

Dr. MASON: There is a concern in North Troy that deals in shoddy and they have a large sign on the top of their building making use of the expression "Dealers in Bats." What is a bat?

Mr. GALLAGHER: I would like to ask if it isn't possible to make cloth out of high grade shoddy?

Dr. MATOS: It is quite possible to manufacture a good grade of cloth with shoddy, but it requires that they should always use a certain percentage of new wool in order to facilitate the spinning operation. Shoddy, after it passes through the carbonizing process, does not possess a fine spinning quality.

Dr. PALMER: I think there is another point that we overlook. Wool fiber is the most sensitive thing in manufacturing. It has a structure similar to a very long elongated fine comb, and the more the wool fiber is worked over the more that peculiar unevenness of the wool fiber is smoothed down, so that old shoddy fiber used over and over again as used in hats and other fabrics loses its filling properties. These peculiar serrations are distinct in new wool fiber.

Mr. HEBDEN: The question has been asked what is a bat. A bat is the product that comes from a card or lapping machine and sometimes is called a lap.

CHEMISTRY OF THE BLEACHING OF COTTON CLOTH

By JOHN C. HEBDEN

Read at the Troy Meeting, June 19, 1914

Cotton fiber appears under the microscope as a twisted ribbon, thicker at the edges than in the central area. The twisted structure gives it the appearance of a spiral. The spirals, however, frequently are reversed, so that there may be spirals turning to the right and to the left on one and the same fiber of cotton. The length of the fiber varies from 2¼ in. for the best Sea Island, to ¾ in. for the lowest grade American cotton. The ratio of diameter to length of staple varies from 1 : 1350 to 1 : 2500. If a single fiber of low-grade American cotton were increased to a diameter of 1 in. and the length of the staple increased in proportion, the fiber would be more than 100 feet long; while if a fiber of Sea Island cotton were increased in the same proportions, the length of this staple would be more than 200 feet long. This extreme fineness, coupled with the twisted structure, makes cotton the vegetable fiber par excellence for spinning.

Composition of Cotton Fiber and Cotton Cloth—The fiber is composed of an outer layer or cuticle, a middle layer containing about 95 per cent of the total fiber substance, and a wall bounding a central canal or lumen, with substances deposited in the lumen. The cuticle serves as a varnish or waterproofing to protect the fiber, and is a mixture of fats, wax and carbohydrates, with some protein and mineral substances; the middle layer is nearly pure cellulose, while the wall of the central canal or lumen, and the compounds in the canal, are principally proteins mixed with small quantities of carbohydrates. The total substances not cellulose amount, on an average, to about 5 per cent of the fiber.

When cotton is carded and spun, practically all of the adventitious impurities are removed. To facilitate the weaving, a sizing composed of starch, fats, soaps, and frequently protein sub-

stances, is added to the warp yarn. The total additions in sizing the warp rarely exceed 5 per cent of the total weight of the fabric. Therefore, as it comes from the loom, cotton cloth, calculated on the dry weight, will contain approximately 90 per cent cellulose, 5 per cent natural impurities consisting of carbohydrates, wax, fat, protein and mineral substances, and 5 per cent of sizing material.

COTTON CELLULOSE—Cellulose must be regarded as a definite aggregate of the products of plant life. It is a typical colloid. At the present state of knowledge it seems impossible to fix a constitutional formula, or to point to as definite reactions for cellulose or for cotton as for bodies which take the crystalline form; but from its reactions it is possible to obtain definite knowledge of its reactivity. The ease with which cellulose enters into definite combinations, as in the cuprammonium and in the xanthate or thiocarbonate reactions, and is in turn regenerated as true cellulose, shows the definite character of the aggregate and the similarity of its reactions to those of other known colloids, as for instance those of hemoglobin. Hemoglobin adds on and parts with oxygen and carbonic acid with ease, without apparently disturbing the power of the aggregate to react, and without destroying the molecule. Many other illustrations might be cited to show the definite character of the reactions of cellulose, and the similarity of these to reactions of other known colloidal molecules or aggregates. Then again the cellulose aggregate may be disturbed in its arrangement, as in the case of the formation of hydro- or oxycellulose. It will then exhibit a wider range of affinities.

On account of the colloidal nature of cellulose and of cotton, it is difficult to remove the small percentage of impurities associated with the fiber, because, like all colloidal aggregates, it readily enters into solutions or unions with other colloids. To break or purify such unions or solutions is usually a long and difficult task. For this reason one can hardly point to a chemical operation for the removal of 5 per cent of simple mechanically bound impurities which requires as many and painstaking operations as the bleaching of cotton cloth.

The cellulose molecule or pure cotton fiber reacts as a saturated compound, and has a percentage composition corresponding to $C_6H_{10}O_5$, and is probably a polymer of this molecule. We consider, in this investigation, that bleached cotton should be pure cellulose and that it has the above composition; we argue that, by making ultimate analyses of cloth taken from the different operations in the

bleaching process, we can follow the different impurities as they are removed or eliminated from the fiber.

NON-CELLULOSE CONSTITUENTS OF CLOTH—If we incinerate the gray or untreated cloth we find a percentage of ash, varying from 1 per cent to 1½ per cent of the weight of the cloth taken. Nearly 25 per cent of the total constituent impurities are represented by this ash. Its composition averages 60 per cent compounds soluble in water, that is, carbonates, chlorides and sulfates of potassium and sodium. The remaining compounds, 40 per cent of the ash, are insoluble in water, and are made up of 10 per cent to 18 per cent of the total ash of phosphates of magnesium and calcium, and the remainder of the carbonates of calcium and magnesium and oxides of iron and aluminum.

If the cloth be treated with boiling water, 1 per cent to 2 per cent of the weight taken will be extracted, removing practically all the potassium and sodium salts, a small percentage of the calcium and magnesium compounds, and some of the fatty acids, wax and soluble carbohydrates. These latter substances are probably removed as an emulsion and not as a true solution.

Cotton, in an ultimate analysis, always gives a percentage of nitrogen and phosphorus. The Department of Agriculture, Bulletin 33, 1896, found, for Upland cotton, that the percentage of nitrogen varied from a maximum of 0.54 per cent to a minimum of 0.20 per cent, with an average of 0.34 per cent. These analyses cover a period of about three years. The percentage of phosphorus, calculated as phosphoric acid, varies from a minimum of 0.05 per cent to a maximum of 0.18 per cent with an average of 0.10 per cent.

RELATION OF THE NON-CELLULOSE CONSTITUENTS TO BLEACHING—The examination of the water extracts, the substances extracted by boiling alkalies, and the ash of cotton have been made by many investigators with fairly concordant results. The determination of the nitrogen content has been made, not only covering American cotton as cited above, but Egyptian and Indian cotton, with concordant results. We are not, therefore, working upon an assumption if we calculate the nitrogen as a factor for determining the percentage of one constant impurity, and the phosphorus not extracted by water as another factor for determining another constant impurity. The ether and alcoholic extracts serve as checks in identifying other impurities, so that, by working from the ultimate analysis of the cloth, that is, the percentage composition expressed as car-

bon, hydrogen, oxygen, nitrogen, phosphorus and ash, we can arrive at accurate estimates of the percentages of the various constituent impurities removed in the different steps of the bleaching process.

The necessity of an investigation after this scheme is emphasized by the failure of the analyses of the water extracts and liquors from the kier boils to give direct evidence regarding the reactions taking place in the fiber and the amounts of the impurities removed. Then again, this method of investigation should pave the way to the discovery of the causes for much of the bad bleaching, spotted and tender goods, and other troubles met in the regular practice of bleaching cotton cloth. Frequently, cloth which has been bleached will yield colors which are clouded or streaked, particularly when dyed in light shades. The usual answer that the goods are poorly boiled is only an apology or an excuse, as it does not define in what way the boiling was faulty, whether the time was too long or too short, whether the liquor was too strong or too weak, or whether the pressure was too high or too low. When goods come from the bleachhouse tender the usual explanation is that the chemick (that is the bleach liquor) or the sour (that is the acid treatment) was too strong. These answers are accepted in face of the evidence that cotton can be subjected to relatively strong solutions of bleaching powder and also to fairly strong solutions of acid without being injured. The question is not asked, how much has the cotton been changed so that its reactivity has been increased, before it was subjected to treatment with the solution of bleaching powder or with the solution of the acid? The increased reactivity of the cellulose, or cotton aggregate, when the molecule or aggregate has been disturbed, has already been referred to. In fact, the usual method given for identifying oxycellulose is based on the increased affinity of this compound for methylene blue as compared with ordinary cellulose or cotton. Cellulose is very readily hydrated and the hydroxy- and oxycelluloses are formed under many varied conditions. While these facts are recognized, there have been apparently no very serious attempts to apply them to the problems of bleaching.

Purpose and Methods of Bleaching—Cotton cloth is bleached to remove the naturally occurring brownish color, the naturally occurring impurities and the sizing material and other products added to facilitate manufacture.

Before the introduction of the use of chlorine as the true bleach-

ing agent, cotton goods were boiled in various potash lyes, steeped in various weak acid yielding compounds, as for instance buttermilk, and then spread on bleaching greens or grass and bleached by the sun and air. Thus originated the terms "grass bleached" or "grass bleach." Bleaching on the green is still practiced to-day to a limited extent, in connection with chlorine bleaching, particularly for linen.

Scheele noted the bleaching action of chlorine, but Berthelot, in 1785, first suggested the use of chlorine, combined with alkali, as a bleaching agent; and shortly afterward, Watt and Tennant put the suggestion into practical operation in Glasgow.

American Process of Bleaching—The present bleaching process dates from about 1840, and is generally known as the "American process." This process consists in boiling in large kiers, with or without pressure, in solutions of lime or caustic soda, or soda ash and soaps. After the boiling process the goods are first treated with solutions of bleaching powder, then with a weak solution of acid, and then washed. The operations are varied greatly according to the quality of the goods and the requirements of finishing, etc., and may be illustrated by the following typical outlines of processes.

Madder bleach, so called because it was used for the production of madder styles and required a very clear white for the illumination of the patterns, consists of the following operations:

1—Singeing.
2—Passage through hot water to prevent the possibility of fire, and storing while wet in bins for twenty-four hours, usually termed "steeping" or "the steep."
3—Washing.
4—Lime boil, usually under pressure.
5—Washing.
6—Treatment with weak acid, usually termed "souring" or "the sour."
7—Washing to remove this acid.
8—Boiling in resin soap.
9—Washing.
10—Boiling in soda ash.
11—Washing.
12—Treatment with solution of bleaching powder, termed "chemicking" or "the chemick."
13—Washing.
14—Treatment with weak acid to remove traces of chlorine and to further whiten the fabric, termed "the sour."
15—Washing, drying and finishing.

This process may be modified by omitting the boiling in resin soap, and boiling instead for a longer period in a mixture of soda

ash and resin soap. The duration of the boiling varies for each kier boil from 6 to 14 hours, and the pressure used from atmospheric pressure to 60 pounds per square inch. A further modification of this process consists in omitting the lime boil, and substituting for the resin and ash boil, boils in a solution of caustic soda with or without the addition of resin or soap. The process then consists of the following steps:

1—Singeing.
2—Steeping.
3—Washing.
4—First caustic soda boil.
5—Washing.
6—Second caustic soda boil.
7—Washing.
8—Treatment with solution of bleaching powder.
9—Washing.
10—Treatment with weak acid or souring.
11—Washing.
12—Drying and finishing.

This process is sometimes shortened still further by using only one caustic soda boil. The time required to bleach cotton cloth varies from three to six days.

The cloth which we have examined in this investigation was taken from goods being regularly bleached by the caustic soda boiling process, as outlined above. The samples taken and examined are numbered as follows:

1—GRAY—From the gray goods before singeing.

2—STEEP—From the goods after being washed after the singeing and steeping operation, referred to as "steep."

3—FIRST CAUSTIC BOIL—From the goods after being washed after the first caustic soda boil.

4—SECOND CAUSTIC BOIL—From the goods after being washed after the second caustic soda boil.

5—CHEMICK—From the goods after being washed after treatment with the chemick or bleaching solution.

6—SOUR—From the goods after being washed after treatment with the sour or acid. This sample represents the goods ready for finishing and printing.

METHODS OF ANALYSIS—Combustions were made to determine carbon, hydrogen and oxygen. The nitrogen was determined by the Kjeldahl method. The phosphorus, calcium and magnesium were determined from the ash. The ether and alcohol extracts were made, using cloth which had been dried to constant weight at 100° C.

All percentages are calculated to dry weight. Table I shows the results of the analyses.

TABLE I

ANALYSIS OF CLOTH FROM THE VARIOUS OPERATIONS OF BLEACHING. ALL PERCENTAGES * CALCULATED TO DRY WEIGHT.

	Gray.	Steep.	First Boil.
Carbon	43.570	40.280	43.820
Hydrogen	6.015	6.400	6.403
Nitrogen	0.191	0.192	0.020
Proteins—N×6.25	1.195	1.200	0.125
Nitrogen after ether alcohol extract	0.161	0.158	
Ash	1.198	0.333	0.103
Ash after ether alcohol extract	0.892	0.372	0.103
Ether extract	0.623	0.589	0.496
Alcohol extract after ether extract	0.782	0.326	0.214
Phosphoric acid before and after extraction	0.030	0.012	0.001

	Second Boil.	Chemick.	Sour.
Carbon	37.620	41.580	44.583
Hydrogen	6.323	5.748	6.528
Nitrogen	0.016	0.015	0.014
Proteins—N×6.25	0.100	0.094	0.088
Nitrogen after ether alcohol extract			
Ash	0.055	0.085	0.061
Ash after ether alcohol extract	0.057	0.076	0.052
Ether extract	0.224	0.201	0.189
Alcohol extract after ether extract	0.230	0.231	0.151
Phosphoric acid before and after extraction	0.001	0.0013	0.001

* Figures are as calculated and are not rounded off.

From Tables I and II we can calculate the changes produced in each operation, and follow the elimination of the various substances going to make up the constituent impurities.

ACTION OF THE STEEP—The action of the steep is, in a measure, to hydrate the cotton, to allow it to take up as much water as possible. The action is slow on account of the colloidal nature of the substance. The water absorbed prepares the way for and assists the scouring action of the boil. In addition to hydrating the fiber, the steep either destroys or renders soluble about one-half of the starch of the sizing, and removes practically all of the soluble salts. By passing the cloth through a solution of malt or other diastase, after the singeing, a

complete resolution of the starch into sugars or other soluble products takes place during the steeping. The quantity of diastase required is very small. The action on the starch by the ordinary steep is due to bacteria and to enzymes naturally in the cotton.

From Table II it appears that, during the steep and the wash which follows, there are removed 70.5 per cent of the constituents represented by the ash, none of the compounds represented by the nitrogen (that is, the protein substances), 5.5 per cent of the fats and waxes represented in the ether extract, and 60 per cent of the compounds represented by the phosphoric acid.

TABLE II

PERCENTAGES OF SUBSTANCES REMOVED BY EACH OPERATION AND TOTAL PERCENTAGES REMOVED AT END OF EACH OPERATION.

	Steep.	First Boil.	Second Boil.	Chemick.	Sour.
Ash	70.5	16.8	8.1	2.4	2.0
		87.3	95.4	93.0	95.0
Proteins	.....	91.5	0.2	0.5	0.5
			91.7	92.2	92.7
Fats and waxes	5.5	14.9	43.6	3.8	1.8
		20.4	64.0	67.8	69.6
Phosphoric acid	60.0	40.0			
		100.0	100.0	100.0	100.0

The goods, after being well washed from the steep, are taken to the boil, having been freed from the soluble impurities amounting to about one-fifth of the constituent impurities and to one-half of the added impurities if no diastase were used, and from all of the added impurities except fats when diastase is used.

Effect of Various Treatments on Cotton—Water, at ordinary temperatures, and even at temperatures corresponding to steam at 60 pounds per square inch, has no action on cotton providing air be excluded; air and steam, however, rapidly break down the fiber. In the absence of air, solutions of caustic lime or caustic soda containing as high as 10 to 20 grams per liter, are without action on the fiber, even at the highest temperatures employed in bleaching. In the presence of air, however, at relatively low temperatures, say temperatures corresponding to steam at 10 pounds per square inch, the cotton is rapidly disintegrated. Strong boiling solutions of caustic soda, say 300 grams per liter, will dissolve cot-

ton. In boiling, that there may be no possibility of attacking the fiber, the solution should not be more than 10 grams of caustic alkali per liter, and the kier should have sufficient volume above the cloth to exclude all air. All air entrained in the pieces when packed should be allowed to escape as the temperature is raised to the boiling-point, and the boil continued for a sufficient time to ensure the escape of all the air. The circulation in all bleaching kiers is from the top downward. I question, therefore, whether, under these circumstances, all the air is ever removed from the ordinary kier.

The lime boil is not a real cleansing operation. The cloth is darker after being boiled than when in the gray. During the boiling the following reactions take place in the cloth: the starch is hydrolyzed and removed; the saponifiable fats and waxes are changed to calcium salts and remain in the fiber; there is fixed on the fiber a percentage of calcium much greater than the equivalent of the fat and wax content of the cloth. In the souring subsequent to the boil, which is always necessary after the lime boil, the calcium salts are decomposed so that the soda boils may remove the fat and waxes. The amount of calcium fixed on the fiber varies from 2 per cent to 4 per cent, expressed as carbonate.

Scheurer, in his investigation of the saponification of the fats in cotton,[1] found 2.88 per cent calcium carbonate after the cloth had been subjected to the lime boil, in addition to the calcium contained in the original fiber. Some observers claim the fixing of calcium to represent a true mordanting. I am inclined to believe that cotton, if in the proper condition, may fix calcium to form a calcium cellulose similar to soda cellulose. After bleaching, or some other treatments, it appears to lose this property of fixing calcium. The fact that cotton cloth which has been boiled and bleached does not produce as brilliant and clear a Turkey-red as cloth which has been simply boiled and not bleached, may be explained by assuming that the fiber is not in the proper condition to fix calcium and thus to ensure the formation of a full alizarine lake.

Scheurer, in the investigation above referred to, has shown that to saponify natural fats when boiling without pressure, the same time is required for both the caustic soda and resin boil and the lime boil; but that to saponify tallow twice as long a period is required for the lime boil as for the caustic soda and resin boil. When

[1] Bull. de la Société industrielle de Mulhouse.

boiling under pressure, however, he found that the caustic soda and resin boil required twice as long a period as the lime boil to saponify both the natural fats and the tallow.

Advantages of Soda Boils—The fact that cotton goods can be scoured and the fatty matters removed in sufficient quantities for the production of a good bleach by either a single boil in caustic soda and resin soap, or by a lime boil followed by a sour and another boil in soda ash lye, has turned the attention of bleachers toward the perfection of the caustic soda boil. The souring operation, which follows the lime boil, is thus eliminated, and the possibility of there being deposits of calcium salts left in the goods, on account of the imperfect souring and washing, is avoided. In the caustic soda boils, however, a good circulation of the lye must be maintained during the whole boiling operation.

Good Circulation of Liquors Necessary—Scheurer, in his experiments, proved conclusively that the circulation of the liquor was absolutely necessary, and that without circulation indifferent results are obtained when using either caustic soda alone or in conjunction with resin or soaps. He also found that, in the case of the lime boil followed by the sour and a soda ash boil, circulation was not important.

Kiers with a positive mechanically controlled circulation should always be used for caustic soda boils. Kiers of the ejector or injector circulating type are not to be recommended, because, in either case, the circulation is not positive. To insure a uniform action throughout the whole mass of cloth, it is the custom to boil and wash, and then repeat the boiling, so that the position of the goods is changed for the second boil. By this procedure the goods which were lying at the bottom of the kier in the first boil will lie at the top of the kier in the second boil. In this manner, a thorough penetration of the lye and uniform treatment are insured.

The saponification and removal of the fats and the destruction of the natural color, which is probably represented in the analysis by the nitrogen content, must precede the real bleaching process. If too small a percentage of the fats and color be removed or destroyed, whites which are not uniform or are not permanent, result.

Wetting Out Test for Efficiency of Boiling Process—There is a rough test used by bleachers to determine the efficiency of the boiling process. This test consists in spotting the piece of dried goods, taken from the boiling or other process, with water, and not-

ing the rapidity of the wetting out of the fabric. The test is best performed by cutting a piece about one inch square from the cloth, taking the precaution to have the edges cut clean and not ragged. If the edges are torn or ragged, the capillarity on the torn parts is not uniform with that of the cut edges, and the water will penetrate into the body of the fabric through the fibers longitudinally instead of transversely as when the edges are cut clean and smooth. By placing these pieces of cloth on the surface of water, it will be found that those pieces which have been thoroughly and fully boiled out sink instantly, but that those pieces which are not as well boiled out take a little longer time to sink, while pieces which have not been well boiled out float for a long time or do not sink at all.

Action of Soda Boils—From a study of Table I it readily appears that the boiling operation is the critical part of the bleaching process, and that in this operation the foundation is laid for the subsequent whitening operation by the action of the chloride. Hence the dictum, "Goods well boiled are half bleached." The principal action of the caustic boils, as illustrated in Tables I and II, is on the protein bodies or nitrogen content. By the combined action of the steep and first caustic boil 91.5 per cent of the proteins are removed, and the second boil removes only 0.2 per cent more. While the boil is usually referred to as an operation for the saponification of the fats and waxes, it appears that the first function of the boil is to remove the proteins, which are almost twice as great in amount in the fiber as the fats and waxes, as shown by the ether extract. The second function of the boil is the removal of the fats and waxes. By the combined action of the steep and the first boil 20.4 per cent of these compounds are eliminated, and the second boil removes 43.6 per cent more. It is apparent, from a comparison of these figures with the percentage representing the elimination of the proteins, that the fats and waxes are less easily removed by caustic soda, and that, after the removal of the proteins, more than twice as much of these bodies is removed in a single boil as was removed by two operations before the removal of the proteins. The fats and waxes of the cotton fiber must, therefore, contain a very large proportion of non-saponifiable matter.

The removal of 87.3 per cent of the constituents represented by the ash, and practically all of the constituents represented by the phosphoric acid, is to be noted as the result of the action of the steep

and first boil, while the second boil removes 8.1 per cent more of the ash constituents.

Dr. Edward Schunk, F.R.S., in an address before The Manchester Literary and Philosophical Society, showed, from an examination of the substances removed from cotton by boiling with alkalies, that the impurities in cotton consist of the following:

1. Pectic acid, soluble in water, reddening litmus, and precipitated by metallic salts.

2. Nitrogenous colored bodies, soluble in alcohol.

3. Fatty acids, melting at 55.5° C., apparently margaric acid or a mixture of stearic acid and palmitic acid.

4. A wax, resembling carnauba wax, soluble in alcohol and ether; insoluble in water and caustic soda.

5. Albuminoid bodies.

The presence of the wax, described by Dr. Schunk as insoluble in caustic soda, explains the low efficiency of the caustic boil as a method for removing the fats and waxes in bleaching.

After washing from the second caustic boil, the analyses show that 91.7 per cent of the proteins are eliminated; that 64 per cent of the fats and waxes, as shown by the ether extract, are removed; that 95.4 per cent of the constituents represented in the ash are no longer in the fiber; and that all of the compounds represented by the phosphoric acid are dissolved from the cotton.

Efficiency of Various Hypochlorites—After the washing from the boiling, the goods are treated with a solution of hypochlorite. This solution is the real bleaching agent. Bleaching powder, that is, hyprochlorite of calcium, or lime chemik, as it is called, is generally used; but recently, owing to the introduction of liquid chlorine as a commercial product, hypochlorite of soda, or soda chemik, is coming to be recognized as a most convenient and reliable bleaching agent. Hypochlorite of magnesia has also been used industrially, but other hypochlorites, as for instance, zinc and alumina, have been tried only experimentally. Magnesium hypochlorite is a most excellent bleaching agent and shows no tendency to form chlorine substitution compounds; its action is purely oxidizing. Calcium hypochlorite has a strong tendency to form chlorine substitution compounds, particularly if the solution be acid. This tendency toward substitution, in addition to its oxidizing action, is one of the drawbacks in the use of lime chemick. Sodium hypochlorite is oxidizing in its action, and has but a slight tendency toward

the formation of substitution products. It is a very active bleaching solution and stands about midway, in its properties, between magnesium hypochlorite and calcium hypochlorite. Sodium hypochlorite forms no insoluble compounds, while lime chemick always fixes a percentage of calcium in the fiber. Each molecule of hypochlorous acid, HOCl, yields one atom of oxygen, which is the true bleaching agent. To treat the goods with the solution of hypochlorite, or chemick, they are saturated in a suitable machine, and piled in bins and allowed to lie for several hours, or they are floated in the hypochlorite solution for a sufficient period to produce the shade of white desired. The action of the chemick in the piling system is hastened by the carbonic acid gas in the air, while in the floating system the solution, on account of its volume, dissolves more completely and more thoroughly the colloidal substances from the fiber. The addition of weak acid, that is, acetic or formic acid, to the hypochlorite solution, to hasten the liberation of oxygen, is not to be recommended, because there is thus an increased tendency toward the formation of chlorine substitution products, particularly when lime chemick is used. The action thus becomes too rapid, no matter what kind of chemick may be used, and is not really under control.

Action of the Bleaching Solution and Souring—The permanence of the protein residue in the cloth is emphasized by the analyses after treatment with chemick. There is removed by the hypochlorite 0.5 per cent of the total proteins of the cotton while there is eliminated 3.8 per cent of the total fats and waxes. By the combined action of the steep and the hypochlorite solution, 9.3 per cent of the fats and waxes are removed, while the first caustic boil removed only 14.9 per cent. These figures seem to indicate that these compounds are removed by mechanical action fully as readily as by chemical treatment. The ash increases from the action of the chemick, due to the fixing of calcium by the cotton. Before we treat the cloth with acid to complete the bleaching, there have been removed 92.2 per cent of the proteins, 93 per cent of the constituents represented by the ash, all of the constituents represented by the phosphoric acid, and 67.8 per cent of the fats and waxes as represented by the ether extract. The souring removes 0.5 per cent of the total proteins, 2.1 per cent of the total constituents represented by the ash, and 2 per cent of the total fats and waxes. So that the bleached cloth shows that, of the total impurities, the following percentages have been eliminated:

95.0 per cent of constituents represented by the ash.

92.7 per cent of proteins.

69.6 per cent of fats and waxes as represented by the ether extract.

100.0 per cent of substances represented by phosphoric acid.

WHAT IS BLEACHED CLOTH?—If we add to the percentage of the above impurities left in the cloth the percentage of the substances extracted by alcohol from the bleached cloth, we arrive at the conclusion that this piece of cloth contains 0.489 per cent of substances not cellulose. Before we accept this conclusion we must consider the fate of the carbohydrate content of the cloth. Starch would give the same percentage composition as cellulose, hence, we cannot expect to differentiate between cotton and starch in an ultimate analysis. We find, however, by qualitative tests, that starch is completely removed by diastase, or by the first caustic soda boil. The other carbohydrates, that is, the pectin bodies, are not identified in the fiber by any known method. The fate of the pectin bodies, as well as the degree of hydration of the cotton in the various operations, seem to be indeterminable.

We gain hints of what might be taking place, however, from the carbon and hydrogen relations, but I do not think we are justified in drawing any serious conclusions. I shall, therefore, leave the interpretation of the carbon and hydrogen numbers, awaiting more definite methods for determining the degree of hydration of cotton and more positive knowledge of the real pectin bodies in cotton. I, therefore, draw this conclusion, that, since the starch disappears completely, and since it is acknowledged that the pectin substances are rendered soluble and dissolved by the methods used in bleaching, it is safe to assume that we have pure cellulose if the carbon and hydrogen numbers correspond to the theoretical, allowing for a reasonable error. I think the numbers found for the goods from the sour meet such conditions.

It is to be noted that some of the original protein constituents of the fiber are soluble in ether or alcohol, or both, as shown from the extracts from the gray goods and from the goods taken from the steep, and that the hydrolyzed proteins left in the fiber after the first caustic boil are completely removed by the ether and alcohol extraction. The phosphorus content does not appear to be wholly associated with the proteins. What the real composition of the ether and alcohol extract is, and what the relation of the phosphorus

is to the proteins, the fats and waxes, and to the inorganic constituents, is the subject of an investigation now in progress.

Importance of Time Factor—Throughout the whole process of bleaching time is a very important element. On account of the colloidal nature of the fiber and of the impurities, it is necessary to allow the reactions to proceed slowly. For this reason bleaching cannot be hastened except with danger to the fabric. The old grass bleach, which required weeks or months as compared with our present bleaching method, requiring days, was a much more permanent and a much more beautiful bleach, because the impurities were removed slowly but completely. Therefore, it is to be recommended that all bleaching operations be conducted in solutions. The piling of the goods, either saturated with chemick or saturated with acid, cannot be as efficient as allowing the goods to lie in solutions.

A simple test to determine whether the bleached fabric is permanent in color consists in steaming the cloth for one hour at a pressure of 5 pounds per square inch. If the color be permanent there is no change in shade, or yellowing, as it is termed; but if the bleaching be not well done or thorough, the white turns yellowish. The change of shade toward yellow, or toward the original color, serves as an index of the quality of the bleach.

Failure of Wetting Out Test—The six samples analyzed, when tested by the wetting-out method described above to determine the efficiency of the boil, and by the steaming method to determine the permanence of the bleached goods, give the following results:

The gray goods and the sample taken from the steep did not sink in water, while all the other samples sank instantly. No difference in the time required for the pieces to reach the bottom of the beaker could be noted in the pieces taken from the second boil, the chemick or the sour. The piece, however, taken from the first boil required a perceptibly longer time to reach the bottom. No better illustration could be given of the failure of tests of this character to give positive knowledge. There is, in the sample taken from the first boil, 79.6 per cent of the total fats and waxes, and in the sample taken from the second boil 36 per cent, or a difference of 43.6 per cent; yet the wetting out tests show no corresponding difference.

But we must, however, note that the sample taken from the first boil showed that 91.7 per cent of the proteins are eliminated.

We must also note that, after the removal of the proteins, more than twice as much of the fats and waxes are eliminated by one boil as are removed by the steep and the first boil. This raises the question, do the colloidal proteins serve as a more efficient water-proofing than the fats and waxes? When steamed, of the samples not bleached, the sample from the gray and the samples from the steep showed the same yellowing, becoming decidedly browner. The samples from the first and second boil showed the same slight yellowing, and the samples from the chemick and the sour hardly changed in tone or shade.

CONCLUSION—From these results we must conclude that the proteins are the cause of the yellowing of cloth in steaming, rather than the fats and waxes. Until we have positive proof that the amounts of the pectin substances present are the cause of yellowing in steaming, I think the above statement is a safe inference from the analytical results.

This investigation has been made in an effort to determine what constitutes a good bleach from a chemical standpoint. It appears from the results that such a definition is possible. It now remains to compare, by the same methods, goods not well bleached with those that are well bleached, and thus determine the definite factors.

PROVIDENCE, R. I.

DISCUSSION.

MAXIMILIAN TOCH: The paper which has just been read has been of a great deal of interest to me, and strictly speaking I ought not discuss it, because I know little or nothing about dyeing. At the same time, color making, as far as organic colors are concerned, is practically dyeing, for the only difference is that while the dyer fastens the color on a substratum of vegetable fiber the color maker fastens the color on a mineral substratum; and as I am familiar with color making I make bold to discuss the paper.

A case came to my notice not very long ago, which demonstrated a test for the permanency of a dyed fabric, and the permanency of a dyed fabric is not sufficiently conclusive if the fabric is tested in fresh water, salt water and soapy water only. A large textile house in England sent me a sample of tropical cloth which they manufactured for underwear, dyed a scarlet red, and largely sold in the torrid zone on account of its non-actinic quality, and they com-

plained that the dyed goods were perfectly permanent to light and fast to all the materials used in the laundry, but were by no means satisfactory when worn next to the skin, for they stained the skin the color of the dye. I found upon investigation and experiment that no tests were given which simulated human sweat, and on subjecting samples of the cloth to a small percentage of butyric acid mixed with weak sodium chloride solution the dye "bled." Human flesh contains both sodium chloride and butyric compounds, which are solvents for the various para dyes. It would appear as if it were essential that such tests should be carried out in determining the fastness under all circumstances of dyed textiles.

OZONE IN VENTILATION

By J. C. OLSEN and WM. H. ULRICH

Read at the Troy Meeting, June 19, 1914

In spite of the fact that a great many investigations have been carried out in recent years on the effect of ozone on air bacteria and odors and also on the physiological effects of ozone, the most diverse conclusions have been reached and opinions expressed with reference to the questions investigated. This confusion is due somewhat to faulty scientific technique and deductions from improperly chosen experiments as well as *ex parte* point of view. The most recent criticisms against ozone in ventilation are found in two articles which were published in the issue of September 27, 1913, of the *Journal of the American Medical Association,* one by Jordan and Carlson and the other by Sawyer, Beckwith and Skolfield on the bactericidal, physiologic and deodorizing action of ozone. A number of errors in the methods used in the experiments given in these articles have been noted and these seem so serious and the articles have been so widely quoted that it seems desirable to correct the misapprehensions which have been produced. Both of these articles refer to the fact that exaggerated claims were made by agents selling ozone machines.

In the article by Jordan and Carlson, it is stated, on page 16, that the concentration of ozone is determined by drawing the ozonized air through a solution of potassium iodide which has been acidified with sulphuric acid. The liberated iodine is then titrated with thiosulphate solution. It is well known among chemists that an acidified solution of potassium iodide is readily oxidized by the ordinary oxygen of the air, and, therefore, if an acidified solution of potassium iodide is used for the determination of ozone, the results will be high. The amount of the error will vary with the concentration of the ozone and may easily give results double the true concentration of ozone. This error can easily be demonstrated by drawing air free from ozone through such an acidified solution of potassium

iodide. It is evident, therefore, that no reliance can be placed on the figures given for the concentrations of ozone which are reported in this article. In the article by Sawyer, Beckwith and Skolfield, the concentrations of ozone were not determined.

It is universally recognized by ventilating engineers who are familiar with the use of ozone that it is of the greatest importance to regulate the concentration of the ozone and that ozone is useful only when employed in the proper concentration. This well-known principle seems to have been so little understood by these investigators that they failed to make careful and accurate determinations of the concentrations of ozone used, and therefore many of the conclusions which they reached are entirely vitiated.

Another very serious error in experimental procedure is found in the tests which were made on the effect of ozone on odorous substances. A considerable number of such substances were experimented with and the conclusion was reached that the ozone *masks* these odors but does not destroy them and that, therefore, ozone is not useful in the removal of such odors.

The method of procedure consisted in exposing the substance giving off the odor until a marked odor was noticed in the small closed room which was used for the experiments. The ozone machine was then operated until a strong odor of ozone was produced. Observations were made from time to time of the odor in the room and it was observed in a good many cases that the ozone odor gradually disappeared and the odor of the substance experimented upon returned. In some cases ozone was again generated until its odor was pronounced and observations again made with reference to the disappearance of the ozone odor and the reappearance of the odor of the substance experimented upon. The conclusion was drawn that the ozone did not destroy the substance giving the odor but masked it; this conclusion was based upon the disappearance of the ozone odor and the return of the other odor. No other evidence, whatever, on this point is presented.

In these experiments, no attempt seems to have been made to determine the amounts of the odorous substances which were present in the air except by the odor. The experimenters apparently did not consider the fact that the odors of substances differ a great deal in intensity and that the quantities of substances which would be present, even though the intensity of the odor was the same, would differ very much. These authors also failed to keep in mind that

the destruction of odors by ozone is an oxidizing process and that this, as well as all chemical reactions, is quantitative in the sense that a definite amount of oxygen is required to oxidize a definite amount of an oxidizable substance.

The following reaction takes place when ozone oxidizes hydrogen sulphide:

$$H_2S + O_3 = H_2O + S + O_2.$$

That is, 34 parts of hydrogen sulphide would require 48 parts of ozone for their oxidation. When the hydrogen sulphide is dissolved in water, the sulphur liberated is still further oxidized by the ozone to sulphuric acid, which would require a still larger quantity of ozone, but according to the reaction given, a somewhat larger amount of ozone than hydrogen sulphide would be necessary for the destruction of this substance. Now, if the intensity of the ozone odor is much greater than that of the odor of hydrogen sulphide, the hydrogen sulphide would be oxidized by the ozone in the experiments reported by Jordan and Carlson and some other authors quoted, and the hydrogen sulphide odor would then return as reported by these investigators.

In order to verify these conclusions, experiments were carried out to ascertain the amount of hydrogen sulphide which will give a distinct odor. A large balloon flask of 30 liters capacity was used. The hydrogen sulphide was produced by treating known weights of carefully analyzed iron sulphide with dilute sulphuric acid. The reacting substances were placed on a watch crystal suspended in the center of the balloon flask. In addition to the odor, tests were made with lead acetate paper.

INTENSITY OF ODOR OF HYDROGEN SULPHIDE

Mg. H_2S per Cubic Meter.	Test with Lead Acetate Paper.	Odor.
977	Very black	Very Strong
244	Very black	Strong
61	Very black	Distinct
30	Turned black slowly	Fairly distinct
15	Brown on edges	Faint
7.6	Turned brown very slowly	No odor

While to obtain a distinct odor of hydrogen sulphide, 61 parts are required, the odor of ozone is very marked when present to the extent of one part per million, the limit being one-tenth part per

million. In the experiments of Jordan and Carlson, the concentration of the hydrogen sulphide must have been from 30 to 60 mg. One part of ozone would have given a strong odor which could mask the odor of the hydrogen sulphide until, by the oxidation of the latter, the ozone was decomposed. Less than one part per million of the hydrogen sulphide would be destroyed by this oxidation, leaving a sufficient amount of hydrogen sulphide to give a very distinct odor. On again generating ozone until a strong ozone odor was obtained, the hydrogen sulphide would be again "masked," and when the ozone odor had disappeared the hydrogen sulphide odor would reappear. This could be done repeatedly as reported by Jordan and Carlson. The conclusion which they drew, however, is entirely unjustified; namely, that their experiments showed that the hydrogen sulphide odor was merely masked and hydrogen sulphide not oxidized or destroyed by the ozone.

In order to verify this conclusion, the following experiment was carried out: A concentration of 25 mg. of hydrogen sulphide was treated with ozone of a concentration of 35.6 mg. per cubic meter. In these concentrations there would be just enough ozone to oxidize the hydrogen sulphide. In this experiment the ozone odor was at first very pronounced but after this odor had disappeared there was no hydrogen sulphide odor. A slight acidity was indicated by the reddening of blue litmus paper. The ozone used had been very carefully tested for nitrous oxides but none was found.

Another experiment was carried out in which the ozone concentration was 13.6 mg. per cubic meter, while the hydrogen sulphide concentration was 60.7 mg. per cubic meter, so that only a small part of the hydrogen sulphide could be oxidized by the ozone present. At first only the odor of the ozone could be detected. The hydrogen sulphide odor gradually returned so that within one hour a faint and after two hours a distinct hydrogen sulphide odor was detected while the ozone odor had entirely disappeared.

This experiment could be repeated three or four times, as reported by Jordan and Carlson on page 33 of their article. They further state: "The mechanism of this masking action of ozone does not concern us here." If the authors had considered the "mechanism" of this action, they might have reached entirely different conclusions, and would have seen that their experiments were in exact accordance with the theory that ozone oxidizes hydrogen sulphide and other substances. They still further refer to the fatigue

of the olfactory end-organs by the ozone. They say "Strong concentrations of ozone rapidly fatigue or anesthetize the olfactory epithelium." One wonders why the authors did not make this statement general and state what every chemist has frequently observed, that *hydrogen sulphide* and the numerous other odors which are present in chemical laboratories produce the same effect on olfactory epithelium, so that these odors are not noticed by workers in the laboratory.

Hydrogen sulphide is also oxidized by the air as is shown by the fact that the odor slowly disappeared in a duplicate experiment in the absence of ozone.

In some cases ozone acts as a catalytic agent. This was shown by the action of ozone on linseed oil. Weighed quantities of linseed oil were exposed to air and ozone. The oil exposed to air gained 17 mg. while an equal quantity exposed to the action of ozone gained 110 mg. during the same time. The amount of ozone generated was 11.4 mg. The ozone, therefore, acted as a catalytic agent, causing the absorption of 82 mg. of oxygen, which is nearly five times as much oxygen as was absorbed by the oil exposed to air alone. It is reasonable to suppose that ozone would act as a catalytic agent and cause the oxidation of other oils and organic substances similar to linseed oil.

In the case of ammonia, the same considerations apply. Ammonia is oxidized by ozone in accordance with the following equation:

$$2NH_3 + 3O_3 = N_2 + 3H_2O + 3O_2.$$

In this case, one part of ammonia is oxidized by about four parts of ozone. A study of the intensity of the odor of ammonia gave the following results:

INTENSITY OF THE ODOR OF AMMONIA

Mg. NH_3 per Cubic Meter.	Test with Litmus Paper.	Odor.
1000	Turns blue readily	Strong
659	Turns blue slowly	Fairly strong
329	Turns blue slowly	Fairly strong
165	Turns blue very slowly	Fairly strong
82	Turns blue very slowly	Quite distinct
41	Turns blue on edges very slowly	Faint
21	Turns partially blue on edges very slowly	Very faint
10	No action	No odor

Experiments were carried out in which known amounts of ammonia were treated with definite amounts of ozone and the ammonia remaining was determined by absorption with sulphuric acid and Nesslerizing. Ammonia is acted upon very slowly so that 24 hours were allowed for the reaction. The concentration of the ozone was 35.6 mg. and of the ammonia, 125 mg. per cubic meter. After 24 hours, 78 mg. of ammonia remained in the flask containing air and 75 mg. in the flask containing ozone. The quantity of ozone present was sufficient to oxidize 8½ mg. of ammonia per cubic meter. The experiment indicates some oxidation of ammonia by ozone. Erlandsen and Schwartz[1] state that their results showed no action of ozone on ammonia.

Experiments were also carried out to ascertain the intensity of the odor of oil of cloves. It was found that 66 mg. per cubic meter would give a strong odor. The amount of ozone necessary to oxidize oil of cloves cannot be calculated exactly, but it would probably require several times more than an equal weight. On subjecting the oil of cloves vapor in a concentration of 36.6 mg. per cubic meter to the action of ozone of a concentration of 33 mg. per cubic meter, it was found that at first a distinct odor of ozone could be detected which gradually disappeared and was replaced by a sweet odor which had no resemblance to the strong odor of the oil of cloves. Very evidently the oil of cloves or one of its strong-smelling constituents is oxidized, at least partially, so as to leave an organic compound having an entirely different odor. The flask was allowed to stand a total of 21 hours although the reaction was practically complete within 2 to 3 hours. The reaction did not seem to be entirely regular. The experiment was repeated several times and the formation of the sweet aromatic substance repeatedly observed, but at times the odor of cloves persisted. Any excess of ozone was removed by shaking with 10 per cent ferrous sulfate solution. Control experiments were also made with a balloon flask containing oil of cloves and air only. Erlandsen and Schwartz have made a similar observation with respect to skatol and indol. They state that these substances are completely decomposed by ozone with the formation of pleasant-smelling substances similar to coumarin. They also state that mercaptan is rapidly decomposed by a large excess of ozone. These authors also found that hydrogen sulphide is oxidized by ozone. Jordan and Carlson also mention the work of Erlandsen

[1] *Zeit. of Hyg.*, 1913, pp. 81–100.

and Schwartz, but state that the results of the latter agree with those of Jordan and Carlson in showing that ozone *masks* odors and does not oxidize the substances discussed. Jordan and Carlson even state that "The inability of ozone to oxidize (to any appreciable extent) ammonia vapor and oil of cloves is very striking." Franklin gives the results of experiments showing the oxidization of a great many organic substances and demonstrated that carbon monoxide is oxidized to carbon dioxide.[1]

Undoubtedly many of the conflicting conclusions which have been reached are due to the failure of experimenters to take into account the quantitative relations between ozone and the substances to be oxidized and have generally failed to realize that on account of the much greater intensity of the odor of the ozone than that of other substances producing odor far too little ozone has been employed in the experiments. The odor of ozone is at least 100 times as intense as that of other substances having a pronounced odor.

The common method of using ozone to destroy odors seems to be justified by these considerations. The ozone machines in good practice are operated so that a very small concentration of ozone in the air is produced. The continued renewal of this small amount of ozone oxidizes the odorous substances and gives the total quantity of ozone required by chemical theory.

Jordan and Carlson undertook to prove that ozone does not destroy smoke by coating a piece of glazed paper uniformly with a thin film of lampblack and subjecting the carbon to the action of ozone for 10 hours, and state that there was no effect on the lampblack. They regard this as evidence that ozone does not destroy smoke, although they state that smoke also contains carbon monoxide, sulphurous acid, etc. They seem to have made no attempt to study the effect of ozone on carbon monoxide and sulphurous acid but state that the assertion that "ozone destroys smoke" is equivalent to a deliberate deception because ozone does not oxidize carbon particles suspended in the air. Not being chemists, Jordan and Carlson might not have known that carbon is extremely difficult to oxidize, but they should have known that carbon monoxide and sulphurous acid as well as creosote and other pungent and aromatic organic substances present in smoke produce disagreeable and toxic physiological effects. It is just these constituents of smoke which are easily

[1] *Heating and Ventilating Magazine*, **10**, No. 11.

oxidized by ozone. The carbon which is not acted upon is totally inert and harmless.

Jordan and Carlson also carried out investigations on the action of ozone on air bacteria. As has already been stated, their determinations of the concentration of ozone cannot be relied upon because acidified solutions of potassium iodide were used which give high results. The authors admit that the plate method which they used was not an exact one and that therefore the results were irregular. They obtained a reduction of bacteria from 64 to 38, 49 to 18, 61 to 67 (increase), 78 to 34; that is, the bacteria were reduced to 40.6 per cent, 63.3 per cent and 56.4 per cent in three tests, while in the fourth there was an increase to 109.8 per cent. Most authors would discard the fourth test and consider the reduction to be about 55 per cent. Jordan and Carlson then tried Winslow's more exact method, but did not use a large enough sample for the test (4.5 liters), so that the highest number of bacteria counted was 7. It is not good practice in bacteriological work to rely on counts of so small a number. Jordan and Carlson draw the following strange conclusion from their results:

"2—The alleged effect of ozone on the ordinary air bacteria, if it occurs at all, is slight and irregular even when amounts of ozone far beyond the limit of human physiological tolerance are employed."

There is no reason to suppose that the ozone used in these experiments was "Far beyond the limit of human physiological tolerance." The reduction in the number of air bacteria is not "slight and irregular." The experimental results of Jordan and Carlson agree with the results obtained by one of us[1] in New York City school rooms showing a reduction in air bacteria and moulds of 75 per cent, 91 per cent and 91 per cent, the greater reduction resulting from longer exposure to ozone. No ill effects were observed on the children and adults present during these tests.

Jordan and Carlson (p. 34) state: "Some bacteria are undoubtedly killed by ozone, especially if they are in a moist condition." This statement is correct as it is generally recognized that ozone destroys moist bacteria very rapidly. The conclusion drawn by Jordan and Carlson is very far from being correct. They say: "In practice, however, the fact is of very slight importance." The works of Chapin, Doty and of Winslow and Robinson have fairly disproven

[1] "Purification of Air and Water by Means of Ozone," Olsen, Fourth International Congress of School Hygiene.

the belief held so long that bacteria existed as a menace in rebreathed air. It has been shown that infection occurs but rarely from air-born bacteria and then only when the *bacteria are in the moist condition.* It is just these virulent bacteria which are quickly destroyed by ozone even in low concentrations. The bacteria which resist the ozone are powerless to transmit disease.

It is by no means necessary to show that ozone is capable of sterilizing the air in order to show that it is useful in ventilation. There is in fact no other disinfectant which can be used even in low concentrations in living rooms. All other known disinfectants are highly dangerous in concentrations high enough to be at all effective. Ozone in low concentrations will both remove odors and will materially reduce the bacteria content of the air.

Jordan and Carlson attempted to show that ozone is dangerous by subjecting guinea pigs to high concentrations until the animals died. They also forced stronger ozone (10 parts per million) directly into the lungs of dogs and rabbits after performing tracheotomy under ether and inserting a tube well below the larynx and treating the wound with cocaine. They say they did this because at least three-fourths of the ozone is decomposed by the mucous membrane of the respiratory passages. It is difficult to see what bearing this experiment can have on the use of ozone in ventilation. The ozone which was forced into the lungs must have been several hundred times as concentrated as it is ever used in ventilation. It would have been quite as logical to place animals in pure oxygen or even in an atmosphere of 50 per cent oxygen and also force these gases directly into the lungs. When the animals died and the lungs were found to be inflamed, the conclusion might be drawn by highly academic experimenters that it is dangerous to breathe air containing 20 per cent oxygen.

Jordan and Carlson carried out experiments with what might be called low concentrations of ozone. They subjected 4 cats, 4 rabbits, 6 guinea pigs and 12 rats to ozone of 1 part per million nine hours daily during two weeks, so that irritation of the eyes and nose was produced. Body weight, appetite and general condition were noted. No ill effects on appetite and body weight or general condition could be observed. The conclusion could, therefore, be drawn that ozone in moderate concentrations is harmless, but Jordan and Carlson warn us that this conclusion is not justified.

They say: "We desire to state, however, that this test does not

warrant the conclusion that the ozone in concentrations that may be used in practical ventilation is harmless to man. Two weeks is a short time in the life of a man. If ozone in ventilation should come into general use, it would mean in the case of office and shop workers exposure to ozone from six to ten hours a day, six days of the week, from nine to twelve months of the year for from twenty to fifty years. And even if this prolonged exposure to ozone should prove harmless to the robust person, what about the unfortunate person whose lungs have only slight power of resistance?"

Jordan and Carlson seem to have fallen into the error of assuming that because they have not tried to, and therefore have not demonstrated actually, benefit from the use of ozone, this is equivalent to having demonstrated the reverse, i. e., the harmfulness of ozone.

If the facts presented in this paper are properly interpreted they will be found to be in accordance with the view that ozone is a powerful disinfectant and deodorizing substance, which, in suitable concentration, is without any injurious effects whatever. The elimination of odor is by no means the least important function of ozone and there is no other agency available except dilution with fresh air. In many cases it is impossible to introduce enough air for this purpose without producing annoying and dangerous drafts of air, not to mention expense of blower installation and operation as well as heating the air. As a matter of fact, before ozone was available, disagreeable odors were often considered unavoidable nuisances which could not be eliminated or overcome.

With reference to the alleged harmful effects of ozone, no single instance of harm to a person from the proper use of ozone in ventilation has been published, but all adverse opinions have been deduced, by inference, as in the paper by Jordan and Carlson, from experiments performed with very high concentrations, while all efforts to produce harm experimentally with weak ozone have failed.

Jordan and Carlson report that twenty-six animals, exposed for fourteen days, during nine hours each day, to concentrations high enough to cause irritation of the eyes and nose, suffered no ill effect whatever. Hill cites the cases of the numerous workers in the London underground tubes who have shown no ill effect in three years. Gminder cites the unharmed workers in the spinning mills at Reutlingen, and numerous similar instances of prolonged proper use of ozone without a single complaint are to-day in existence.

The Jordan and Carlson report is the most elaborate and convincing laboratory test that has been published.

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DISCUSSION.

C. M. JOYCE: I was interested in Dr. Olsen's results with the use of ozone as I had concluded after listening to a symposium on ventilation at the Chemists' Club recently and from a personal experience with ozone that it had little industrial value.

I watched a trial of ozone as a deodorizer in a factory room where the odor of benzine vapor is always strong. The generator was put in on the recommendation and under the direction of an agent of one of the large companies and run for several weeks according to directions. During this time the odor of benzine could not be detected, but the characteristic odor of ozone was there instead. I found it more unpleasant to stay in the room than before the generator was put in and the workmen complained of throat irritation to such an extent that the use of ozone in the room was finally abandoned.

Dr. OLSEN: I do not believe that benzine vapor is oxidized by ozone.

HARRY BARKER, Associate Editor, *Engineering News:* I have had the opportunity of a very short but direct discussion with Dr. Jordan on the work covered by the report which Prof. Olsen criticises. As a result I think I might add a few remarks to the discussion in order to show what I consider the proper light in which the Jordan-Carlson experiments are to be regarded.

It was intended that the experimental procedure should fall into two groups: (1) those upon the bactericidal, deodorizing and physiologic action of ozone in sufficiently great concentration to give marked action; (2) those upon the possible action of ozone (in these three fields) with such concentrations as are permissible in ventilation. The first phase of the procedure was primarily of scientific interest, while the second was essentially of practical application. These gentlemen have insisted that the studies with high concentration were intended to throw light on the mechanism of the physiologic action of ozone, for instance, and the information which they claim has been secured is not to be transferred and applied to ozone at low concentration.

While Messrs. Jordan and Carlson are reputable investigators, holding degrees of Doctor of Philosophy, yet a comparison of their studies and the criticisms of Prof. Olsen must show that their procedure in studying deodorizing has been weak from the chemical point of view and no doubt they will welcome technical criticisms of the type which Prof. Olsen makes. I have failed to find any animus in them, and think they seek the truth. Indeed, comparison of the work of these two groups of investigators shows that there is no discrepancy between them. The fault with Jordan and Carlson's work is that they did not recognize the quantitive scrutiny which should have accompanied their work before they could ascertain whether partial oxidation or only masking had been observed. They did not push their work far enough.

Moreover, in using ozone from the small machines, as they did, they secured only low concentrations (great dilutions would better express it) and ozone probably of lower activity than that producible otherwise. There is evidence that where it is possible to produce ozone with the higher voltages, 10,000 to 20,000 in place of 5000 to 10,000, the molecular arrangement is different. The formula is then not O_3 but O_4, O_5, O_6 or even as high O_{10}.

The smoked-paper tests have excited much amusement among engineers and chemists. The idea of expecting anything else than what happened is, of course, preposterous, but the reason for these trials possibly puts a slightly different face on their inclusion in the report. The attitude of the investigators was that it is one thing to declare to laymen and even to medical men that the destruction of carbon particles by ozone cannot possibly take place, while it is decidedly another thing to demonstrate that it does not and their experiments were taken to the latter end. Some of us believe that, when the advertisers of ozone apparatus have declaimed about the ability to "destroy smoke," they have meant the oxidation and consequent disappearance of visible volatile matter. Yet that has not been the impression secured by a considerable number of people. The investigators underfire would have done well if they had attempted to discover the whole truth of smoke destruction rather than merely to furnish the obvious demonstrations that solid carbon particles are untouched.

The claim of Drs. Jordan and Carlson, as I understand it, regarding their low-concentration studies, is that no *measurable* physiologic action is appreciable with any concentration that would be tolerated

in ventilation work. As soon as the concentration rises to produce a measurable physiologic action, that action is unfavorable. If the studies of these gentlemen showed that the only *demonstrable* action was unfavorable, as medical men their opinions and recommendations, made thereafter against the use of ozone in any concentration, are reasonable from their point of view. If they err they err on the side of safety.

The only medical man whom I know of as markedly in opposition to the views of Jordan and Carlson is Dr. F. V. Wooldridge of Pittsburgh, who has worked with ozone at the Pittsburgh Homeopathic Hospital for some seven or eight years now. I have had the opportunity of discussing his work first-hand with him and so can appreciate the differences which exist in views. A brief statement of Dr. Wooldridge's work and opinion is to be found in *Engineering News,* April 9, 1914. His studies of bactericidal action in dry air showed that with a concentration of three mg. per cubic meter there was no appreciable effect and only a slight inhibition at a concentration of six. However, if the air was kept moist there was a decided inhibition at a concentration of three and a marked germicidal action with a concentration of six. (It should be noted that these concentrations were determined by the potassium-iodide tests and so are subject also to Prof. Olsen's criticisms.) Some of the smaller machines that have been advertised were used afterwards by Dr. Wooldridge and unless the regular equipment of the hospital was used not even an inhibitory effect could be found, due to too low concentrations, possibly. (In this institution there is a battery of five generating units of the Girard type.)

In regard to the deodorizing effect of ozone, Dr. Wooldridge interprets his results as indicating that ozone without fail destroys organic odors and many inorganic odor substances. His idea is that these are broken up first by oxidation of the sulphur and hydrogen with which the odors are rich.

In regard to the physiologic and therapeutic actions, he cites his own experience of spending eight months (working hours I suppose) constantly in the presence of the gas in amounts greater than were necessary to destroy organic odors, during which time he enjoyed the best of health. A few hours' trial was purposely made in a room where fresh ozone at a concentration of two was being supplied. As we would expect, there developed irritation of the eyes and mucous membrane of the nose, together with a constricted

sensation of the larynx. In one hour a dry, hard, persistent cough developed which lasted for four hours and left the chest raw. One man under his observation breathed concentrated ozone for an hour and in addition to the above symptoms noted was afflicted with such an asthmatic condition that oxygen and aromatic spirits of ammonia were used for relief.

Dr. Wooldridge prefers a small ozone-generating outfit in the room with pneumonia patients to any other adjunct and in the treatment of whooping cough he thinks it is at its best—in modifying the paroxysms and increasing the ability to accept nourishment. In tuberculosis he thinks that ozone seems to stimulate the centers of nutrition in some way. But in none of these uses does he find that ozone in concentration agreeable to the human organism will affect the bacteria ejected into the air by a patient and he has repeatedly stated that any real therapeutic value which the gas has must be recognized as distinct from its germicidal action.

Now these assertions are very interesting, but I feel that we must admit that they are open to the criticism which other medical men have made—that they do not furnish *adequately controlled* tests of therapeutic effect. The gas has not been used alone and there is no way of telling whether the recoveries are due to the other medicaments, psychological influence, or perhaps to spontaneous action. Somewhere between the very optimistic attitude of men like Dr. Wooldridge and the very skeptical feelings of others like Jordan and Carlson the truth probably resides. We may not agree with the skeptics, but we cannot severely censure them for keeping their formal expressions of opinion altogether on the safe side of the unknown location of the exact truth, for as engineers it is wise to employ large "factors for safety" since these are but "factors of ignorance."

THE PRESENT PATENT SITUATION

By MAXIMILIAN TOCH

Read at the Troy Meeting, June 19, 1914

On February 1st, 1913, the new rules or procedure in patent litigation became effective, and after fifteen months a calm review of the benefits derived from the new rules is opportune. To those who are unacquainted with these new rules let me state briefly that the old custom of patent litigation was in taking of testimony before a Master, in the office of either the defendant's or the plaintiff's attorney, and this Master came in to swear in each new witness, but never remained, and even if he did remain, he had no authority to decide upon the propriety of the questions asked. The testimony was taken down invariably in long-hand. The costs were appalling, for the fees of a patent attorney are from $50 to $100 per day, the fees of the experts are the same, the cost of printing or typewriting is very great, and although it has often been said that no poor man can litigate a patent, I know that no man in medium circumstances can fight one either, for in six months $20,000 can disappear faster than ice under the mid-summer sun.

The new rules in themselves are excellent. They provide that the testimony shall be taken in open court before a judge; they provide that the testimony shall be taken in shorthand, and a very important case can be finished in nineteen working days and even less; and if a judge is not overwhelmed nor overburdened with work, he can render a decision within a month thereafter. An excellent feature of the new rules is, that upon petition, the opposing experts will be required, within a certain number of days after the case has been put at issue, to file their expert opinions in the form of an affidavit, so that each side will have these affidavits before them as a basis for preparing for cross-examination of the expert witnesses in open court, and to enable them to see each other's positions, as far as these affidavits will disclose the same, in order to enable them to produce such fact witnesses as they may deem it necessary to

produce to meet the attacks which the affidavits may indicate will arise. This to a considerable extent relieves the new practice from the surprises that may be sprung at the trial, and which, from the nature of surprises in the expert side of the case, would make it almost impossible for the opposing party to meet, since such matters frequently require experimentation. The affidavit of the complainant's expert witness, of course, is required to be put in first, and a certain number of days afterwards that of defendant's expert. The cross-examination of the experts is conducted in open court.

My plaint is that we are suffering under the régime of a parsimonious republic. In the great Southern District of New York there are at this writing but four judges who are available for patent work; one of them has resigned, one of them is on leave in Europe, and the other two are staggering under a mass of litigation. Nor is it to be assumed by any means that a federal judge is a patent judge only, for in one day I have heard motions on questions of immigration, questions of bankruptcy, questions of inter-state business relations, questions of injunctions in matters already decided, and questions of trademarks, questions of copyrights, and questions of patents; so that a judge must needs be keen of eye and ear, clear of mind, and in the finest physical and mental condition possible to withstand the terrific onslaughts that are made upon what should be otherwise a man of mental equipoise.

In the parsimony of our republic the Attorney-General of the United States has decided that the vacancy which exists in this district shall not be filled with a new judge, for the $7500 meagre and insignificant salary can be saved if a judge from some other district will occasionally come down and sit in the place of the one who resigned. In the meantime, infringements go on, injustice is meted out right and left, decisions cannot be had on cases pending on account of the overwhelming amount of work which crowds the dockets—all because our parsimonious, and, in this instance, penuious Government seeks to save a sum so insignificant in the business affairs of this Government, that it is hardly worth mentioning. If it were a real saving nobody could criticise it, but it is not even a saving—it is a hardship, and has a destructive influence on the intellectual property of this country. I do not advise the building of one battleship less per year, but the building of only one battleship less for all time would give a fund sufficiently great to give us a new patent office building, which is so sorely needed, even though

the money is at present available, and the interest on the balance at four per cent between the cost of this building and the cost of a battleship and its equipment, and the saving in the cost of maintenance of such a battleship, would give us fifty more judges throughout the United States, at a decent living wage, and place this country in the position that it should have been placed years and years ago.

It is absurd that the United States Government should issue a patent for a consideration after making its usual objections and a more or less thorough search, and then repudiate its own action; but after spending a fortune and getting a decision, it will only cover *one* circuit in the United States. Even the man who has recovered a decision on appeal could only say, "one-ninth of my country, 'tis of thee, sweet land of liberty," for such a man stands in danger of having a judge in another circuit over-throw what was done in the one; and where the philosophy, the justice, the reason, the sense and the equity comes in, I fail to see, for if the United States Government is a sponsor for a patent, it should be a sponsor for the entire United States, for it was so incorporated in the bond that was made between the fathers of this country and the people who sought their freedom and independence that each man shall have the right to pursue in peace his trade, and the exclusive right for a limited time shall be given to every inventor.

All that inventors want is the same protection as is given to real property or other personal property. If you buy a piece of real property in the United States, a search is made and title passed, and once you have it, it is almost impossible for anyone to deprive you of your ownership. In the purchase of other personal property the title is implied, for you are accustomed to buying from reputable people, and only in the case of stolen goods can the dispute of ownership be had; but when a man makes a new and useful invention it costs him almost all that he has to prove that the invention is his, and even after he has proved it he cannot collect damages excepting by due process of law. Let us hope that within a reasonable time the ownership of a patent will be the equivalent to the ownership of real property or other personal property.

It is puerile for anyone to say the whole trouble with the patent situation to-day is the fault of President Wilson or Mr. Oldfield, or ex-President Taft. As a matter of fact, it is no one man's fault. Ex-President Taft sat in judgment on many a patent case when he

was a Supreme Court Judge of the State of Ohio, and he, better than anyone else, was aware of the shortcomings of the patent situation; and under his administration, I believe, it was largely by reason of his personal interest and experience on the bench, that the new equity rules were promulgated. Inasmuch as this is not a one-man-government it is not within the province of anyone to make any personal criticism. It is as much your fault as it is mine. What we are trying to do is to amend the situation by showing up the weaknesses that exist.

In closing, I recognize my wail for the present is more judges. Some other battle scarred veteran of the patent courts wants the German system of six months publicity; a third man wants a Patent Commission; and so it goes on, but let me say that if every one of us had our wish, and they were the only improvements and remedies for the present, it would help a great deal.

DISCUSSION

Richard K. Meade: This matter was quite fully discussed in the *Engineering Record* of May 16, and possibly some of you have seen this. The article bears out the carelessness with which examinations and searches are made in the Patent Office. Each examiner is expected to do too much work. I believe the number of applications that each passes on is upwards of three per day.

The discussion in question related to a patent which was obtained upon a method of testing the soundness of Portland Cement by boiling the test pieces at a high pressure instead of under atmospheric conditions. The inventor was very much carried away with the value of the test and so applied for a patent on it. The Patent Office, after raising some objections and forcing him to modify his claims somewhat, finally granted him a patent on his method of testing.

The *Engineering Record*, stirred up by a storm of protest from the Cement Industry against the granting of this patent (the reasons for which need not be gone into here), sent a representative to Washington to investigate the matter. This representative found that the examiner had evidently made a very hasty examination of the literature on the subject. The card index in the Patent Office gave many references to high-pressure boiling tests

and it is very evident that the examiner did not follow up these references or he would certainly not have granted this patent.

As showing an error which might often creep into such examinations, modesty may permit me to say that the book which he consulted happened to be my own work on Portland Cement and the latest edition of this. This edition does not mention the high-pressure boiling test for cement because this test was considered obsolete at the time this edition was prepared. The early edition of the book, however, does make mention of this test. This would seem to indicate that the present-day literature of a subject is not always the best source of information and that the older books and editions should also be consulted.

It is certain that the Patent Office needs reconstruction all around. There may be, and probably there is, nothing wrong with the personnel of the Board of Examiners or with the Commissioner. There are certainly, however, too few examiners and too much work is expected of these.

In view of the fact that the Patent Office has turned into the Treasury over $7,000,000 more than it has spent, it certainly seems that the Government could afford to properly equip this department. I have advocated a consulting board of practical experts familiar with the arts who could be called in by the examiners, and I believe that such a board would prevent the granting of many useless patents and make those which are granted carry much greater weight.

THE DEVELOPMENT OF THE ROTARY KILN AND ITS APPLICATION TO VARIOUS CHEMICAL AND METALLURGICAL PROCESSES

By RICHARD K. MEADE

Read at the Troy Meeting, June 19, 1914

Black Ash Revolvers—As early as 1848, W. W. Pattinson, an English chemical engineer, invented a revolving black ash furnace, but the furnace as he built it was not a success. It remained for Elliott and Russell some five or six years later to design a furnace which would operate successfully, and this was employed in the works of the Jarrow Chemical Company, South Shields, Eng., where the practical difficulties encountered in its operation were overcome by J. C. Stephenson. The apparatus became quite popular after this and was generally introduced into alkali works both in England and elsewhere.

The black ash furnace or "revolver" (Figs. 1 and 2) consisted of a horizontal cylinder of wrought iron about 30 feet long by 10 feet in diameter, lined with firebrick and provided with two bearing

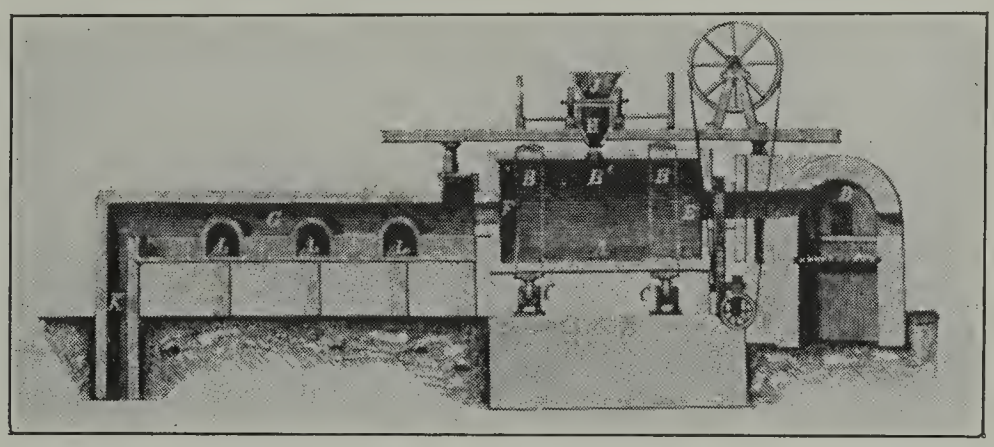


Fig. 1.—Soda-ash Revolver.

rings or tires of steel, which rested upon four small flanged wheels, or rollers. The cylinder was revolved by means of a girth gear meshing with a pinion, which latter was driven by means of a small steam engine. The cylinder was provided with openings at either

end, communicating with a furnace and a lye evaporator respectively. The gases from the furnace passed through the cylinder and melted the charge, the cylinder being revolved meanwhile. The waste gases passed over into the lye evaporator, and the heat was utilized there. The furnace was not continuous, but was operated by charging the materials (a mixture of salt cake, Na_2SO_4, limestone and coal) into the cylinder through man-holes in the side of the former, from hoppers placed above the cylinder. These openings were then closed by suitable covers and when the charge was finished the covers were

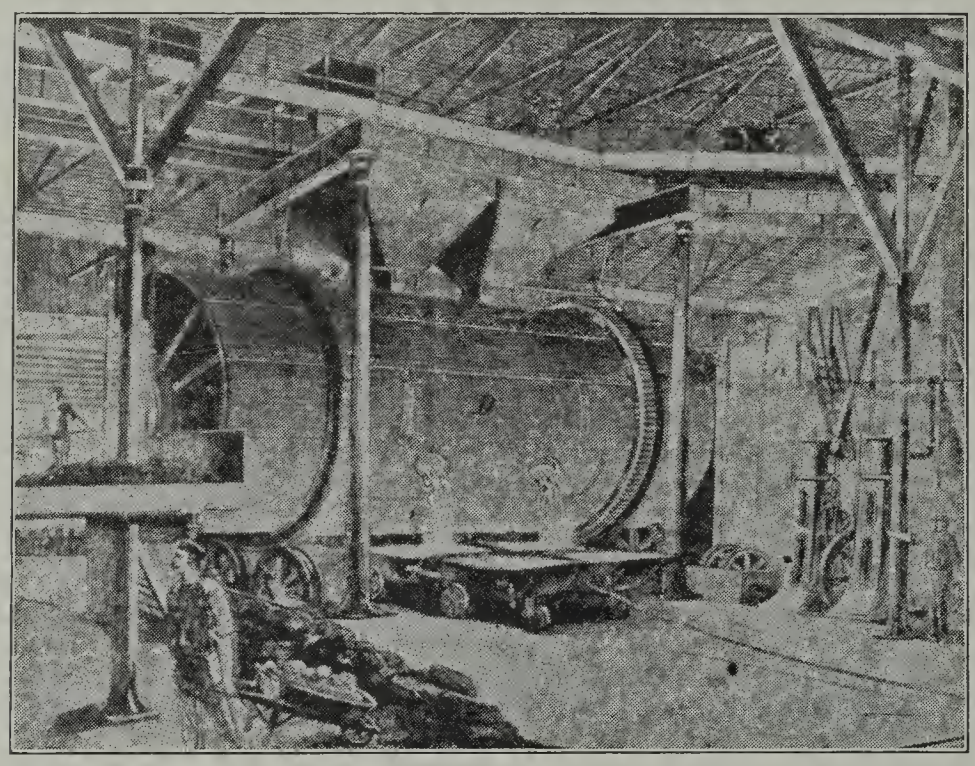


FIG. 2.—Soda-ash Revolver, Emptying the Charge.

removed, the furnace tilted and the molten charge poured through the openings into cars placed below.

REVOLVING METALLURGICAL FURNACES—The counterpart of this furnace is found in the metallurgical industry in the Brückner ore roaster, largely used at one time in this country for calcining and desulfurizing copper ores. The Brückner roaster does not materially differ from the soda revolver except that the evaporator flue is omitted and often the firebox is a car running along a track at right angles to the center line of the furnaces. In this way, the car can be connected with any furnace and allowed to remain there until the sulfur ignites, when it may be wheeled to the next cylinder and a current of air allowed to pass through the first cylinder to burn off the sulfur.

In 1869, Siemens, the celebrated English metallurgist, applied a somewhat similar furnace (Fig. 3) to the manufacture of steel direct from the ore and Danks, of Cincinnati, Ohio, about this time

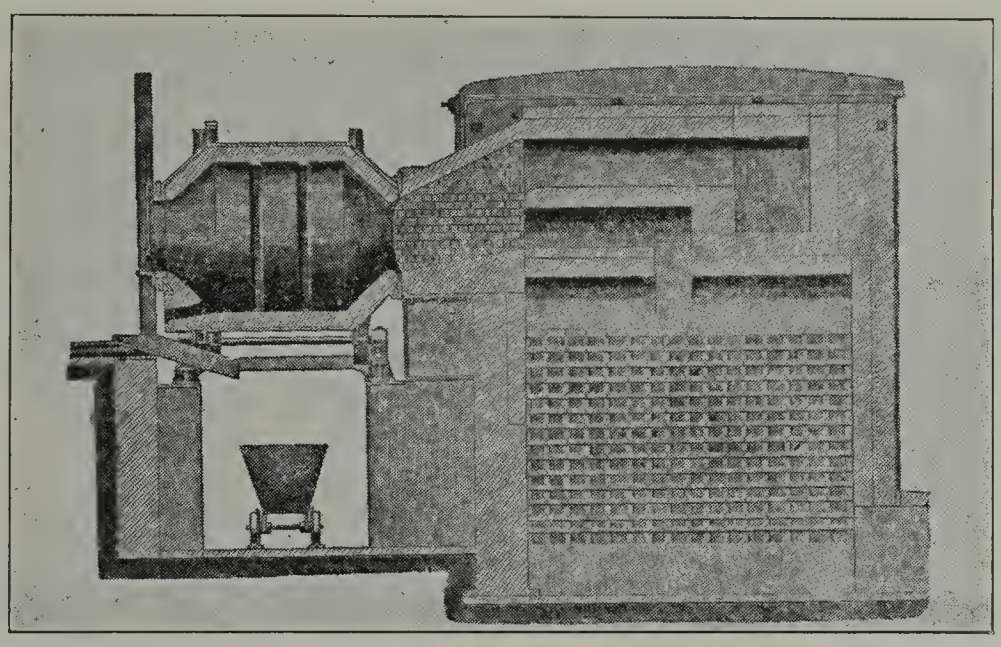


FIG. 3.—Siemens Revolving Steel Furnace.

invented a rotary puddling furnace which worked upon the same principle. Both the Siemens and the Danks furnace were extensively used.

Crampton, another Englishman, in 1872, took out a patent upon a rotary puddling furnace (Fig. 4). He proposed to heat his

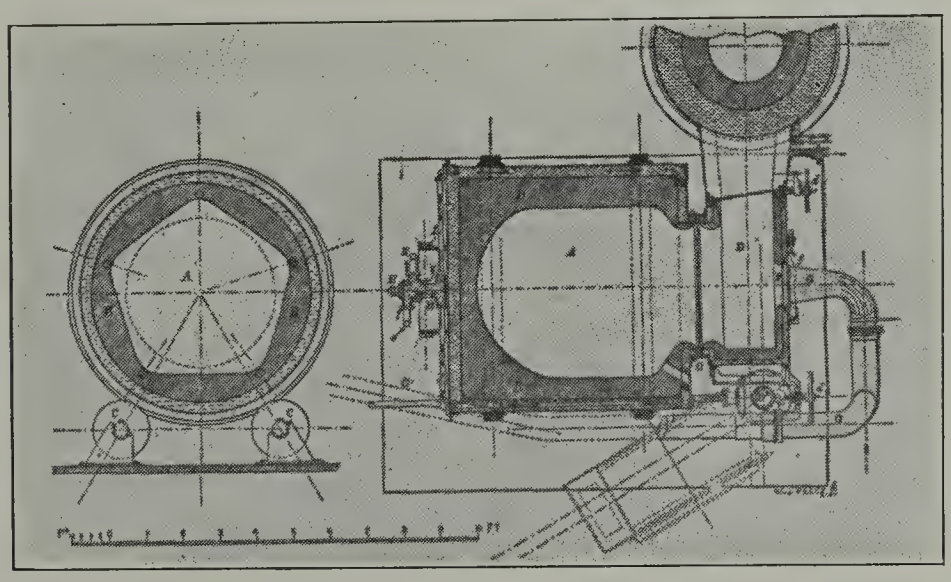


FIG. 4.—Crampton's Rotary Puddling Furnace.

furnace, however, with powdered coal. Crampton's first furnace was used at Woolwich Arsenal, in 1873, and also at other English iron works. His furnace differed from those of Siemens and Danks

in that the cylinder was open at one end only, the jet of fuel and air being blown in below while the gases passed out above.

Crampton evidently understood the value of pulverized coal. It is of interest to note that this form of fuel, after nearly twenty years of successful use in the cement industry, is just beginning to be used to any extent for puddling iron, and yet Crampton suggested that it be so used over forty years ago. His furnace was designed not only to save the labor of fettling and rabbling the iron, but also that of stoking the coal on the grate.

THE ROTARY CEMENT KILN—A few years after this, Crampton conceived the idea of using a rotary furnace heated by pulverized coal for burning cement, but, although he took out a patent in 1877 on his process, I can find no mention of his ever having put his invention into practical use.

In 1885, an English engineer, Mr. Frederick Ransome, received a patent upon a continuous rotary furnace process for burning Portland cement. Ransome's furnace differs from those which have been mentioned above in that it consisted simply of a straight cylinder, supported upon rollers and revolved by gears, tilted slightly at an angle to the horizontal. The effect of this tilting was that when material was fed into the upper end, the revolutions of the cylinder caused the material to move through the furnace. As the lower end was left entirely open the action of the furnace was continuous, the material to be calcined passing in at the upper end and the burned material out at the lower in a steady stream. This is the present-day "rotary kiln" (see Figs. 6 and 7).

Ransome's idea was faulty in that he expected to eliminate the necessity of grinding the burned clinker by his process rather than to effect any economy of labor or fuel in the burning process itself. His idea was that by calcining the raw material in the form of a fine powder in such a furnace the clinker so obtained would be fine also and hence would not need to be ground. He entirely overlooked the fact that semifusion must take place in order to form Portland cement, and that in this condition the material would be sure to stick together and form small nodules. Instead of making a clinker easier to grind, the rotary kiln made a clinker much harder to grind than that burned by the upright kiln. Ransome's process was given quite a prolonged trial at a cement works at Grays, Essex, England, using gaseous fuel, but did not prove commercially successful.

In the same year, H. Mathey, of New York, took out a patent

upon a revolving furnace (Fig. 5), somewhat similar to that of Ransome except that, instead of inclining his furnace, he obtained the same effect by having the center line of the kiln horizontal, but the kiln itself was made slightly cone shape, the material being fed in at the smaller end. He proposed to heat his kiln by a grate fire, and to employ it for burning lime and hydraulic cement.

In this country, a small cement plant in Oregon attempted to use Ransome's kiln, in 1887, but the attempt here too proved a failure. About the same time the Atlas Portland Cement Company began to experiment with Ransome's kiln, first at East Kingston, New York, on wet materials, and latter with success upon the cement rock of the Lehigh District in Pennsylvania. In Ransome's original patent, he proposed to heat the kiln by producer gas, but its de-

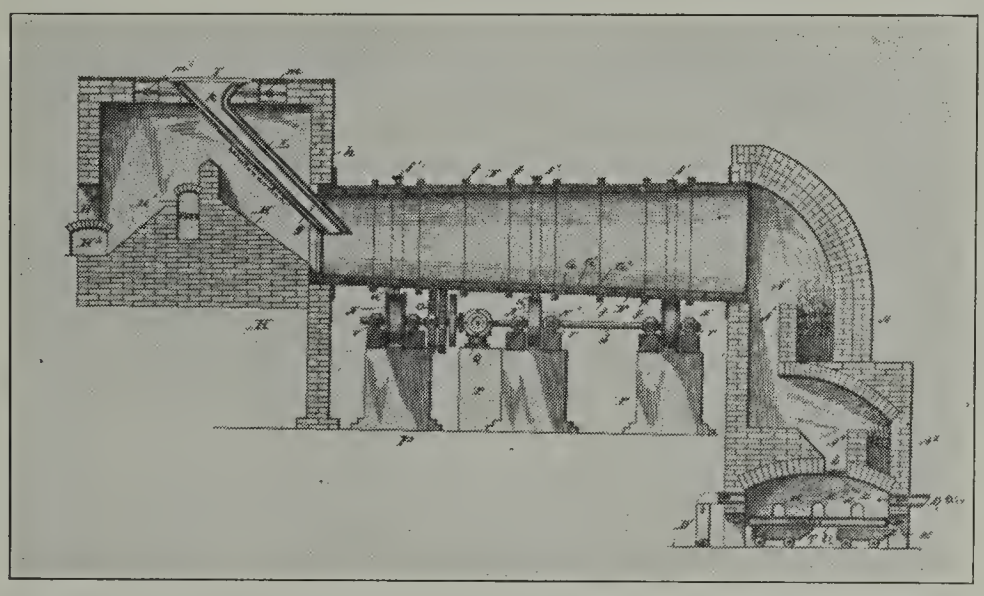


FIG. 5.—Mathey's Revolving Lime and Cement Kiln.

velopment in this country was made possible by the use of crude oil. At first these kilns were only 40 ft. long, but it was soon found more economical to lengthen them to 60 feet, and now the usual length is between 100 and 150 feet with diameters ranging from 7 to 9 feet.

The rotary kiln came quite generally into use in this country following the results obtained by the Atlas Portland Cement Company. About 1896, powdered coal in place of oil came into use and from that time on, all new plants for the manufacture of Portland cement installed rotary kilns, employing pulverized coal as a fuel, except in localities where oil or natural gas are cheaper. Practically all Portland cement made in this country and much of that in England and Germany, is now burned in rotary kilns.

It is not the purpose of the present paper to treat of the employment of the rotary kiln in cement burning, as the literature obtainable on the subject is voluminous, but instead to call attention to its employment in other industries, and to suggest new uses to which it may be put.

DESCRIPTION OF THE ROTARY KILN—The rotary kiln (Fig. 6), in its usual form consists of a cylinder, from 6 to 9 feet in diameter, by from 60 to 150 feet long, made of steel sheets from ½ to 9/16 inch in thickness, lined with firebrick, and inclined at a pitch of from ⅜ to ¾ inch to the foot. The steel sheets are held together with single strap butt joints, as these joints resist expansion strains

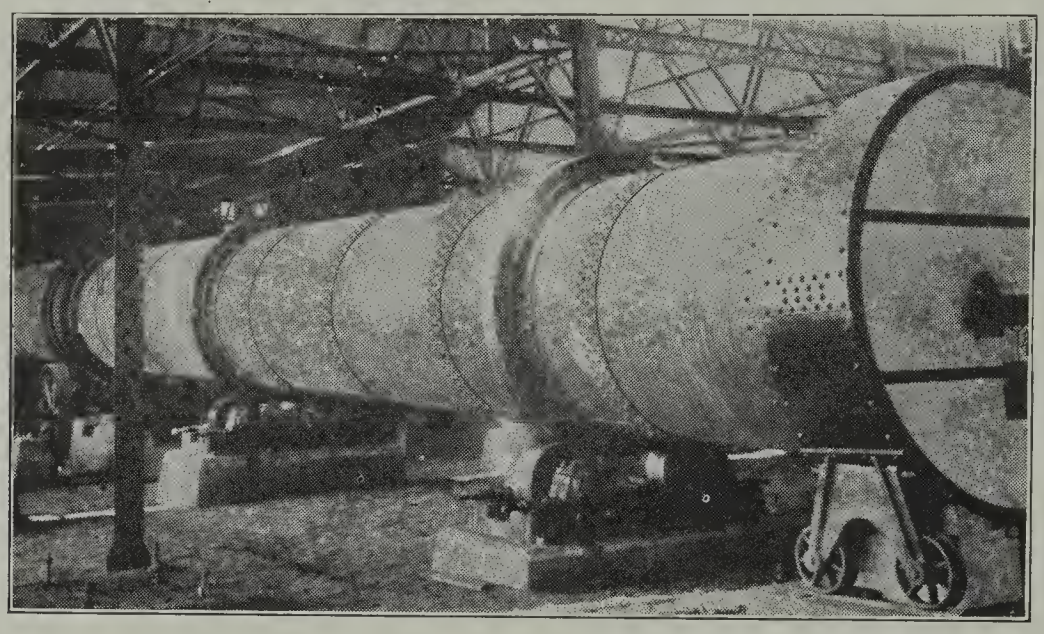


FIG. 6.—Rotary Kiln.

due to heating better than lap joints. This cylinder is supported on two or more tires made of rolled steel, and having a face of from 6 to 12 inches and a thickness of at least 4 inches. They run each on heavy friction rollers made of cast steel, which are often mounted in pairs on a rocker. The kiln is driven by a girth gear situated usually near its middle or upper end, and a train of gears, actuated either by a line shaft or a motor. The upper end of the kiln projects into a brick flue which is surmounted by a steel stack. The flue is provided with a door at the bottom to take out the dust which accumulates there.

The lower end of the kiln is closed by a hood into which the kiln projects. Sometimes this hood is made stationary with movable firebrick doors, but oftener it is mounted on a movable carriage. The front wall of the hood is provided with two holes, one for the

entrance and support of the burning apparatus, and the other for observing the operation of the kiln and for inserting bars to break up the rings formed and repair the lining. The lower part of the hood is partly open and through this the clinker falls. Air for combustion also enters here. Fig. 6 represents a completed kiln.

The usual diameter of a 60 foot rotary kiln unlined is from 6 to 7 feet, of a 100 foot rotary from 7 to 8 feet, and a 125 foot rotary 8 to 8½ feet. Most of them are made the same diameter throughout, though some of them are made, say 6 feet 6 inches in diameter for the first 30 feet, and then taper through 10 feet to a diameter of 5 feet 6 inches for the remaining 20 feet; others taper for the last 10 or 15 feet before entering the stack. This latter plan has the effect of a damper, crowding the heat more to the front of the kiln. It probably lessens the output somewhat, since the choking cuts down the amount of coal that can be burned.

The short 60 foot kilns usually bear upon two or three tires and longer kilns often on four or more tires. The kilns are always provided with two or more horizontal thrust roller bearings to keep the kiln on the vertical roller bearings.

The material to be burned is fed into the kiln through a horizontal water-jacketed screw-conveyor, or more generally spouted directly into the kiln through an inclined pipe of cast iron. Wet materials are often pumped directly into the kiln. The raw material feeding device is attached directly to the driving gear of the kiln so that when the kiln stops, the feed also stops. The material to be burned is stored in large steel bins above the feeding device, so that a constant and regular supply may be always at hand.

The kiln is heated by a jet of burning fuel, usually powdered coal where the ash of this is not objectionable. Where the ash of the fuel is objectionable producer gas is usually employed. Where oil or natural gas are cheaper, they are always used, as they are also the most convenient fuel.

Nodulizing Ores, Cinder, etc.—About 1900, various metallurgists were experimenting with the rotary kiln for nodulizing flue-dust, fine iron ores, etc. Edison conducted experiments, for example, on the nodulizing of the fine concentrates obtained from his magnetic separators, and several iron and steel concerns experimented with the use of the kiln to nodulize flue-dust and fine iron ores. Within a few years, plants were established for the latter purpose. The Pennsylvania Steel Company were among the early

users of nodulizing kilns, employing one on Cornwall concentrates. From about the year 1904 on, the patent office has issued many patents on various processes for nodulizing ores.

The rotary kiln has furnished a simple means of utilizing the soft clayey ores, such as that of the Mayari field in Cuba. Practically all of the schemes tried for placing this ore in satisfactory condition for the blast furnace were unsatisfactory until the rotary kiln was tried. The plant in Cuba now consists of twelve kilns 100 feet long (eleven of these being 10 feet and one 9 feet in diameter), and has a capacity of from 1500 to 2000 tons of nodules per 24 hours.

Chemical manufacturers also began about 1904 nodulizing pyrites cinder or "blue billy," selling the nodules to the blast furnaces. This was possible because the process not only nodulized the cinder, but also desulfurized it. This practice has now become quite general and nearly all large sulfuric acid manufacturers whose locations permit of a ready sale of the product to the blast furnaces, now nodulize their cinder. When copper bearing pyrites ore is roasted for the sulfuric acid and then leached for the copper, the iron oxide residue is now nodulized and sold to the blast furnaces, the wet residue being conveyed direct from the leaching tanks to the kiln.

During the past year, a great deal of interest has been aroused in the possibility of treating fine copper ores and smelter flue-dust in the rotary kiln. A rotary kiln has now been working successfully on such material at the plant of the U. S. Metals Refining Co., Chrome, N. J., for over a year. The fine ore question is a very serious one to the copper smelter, because of the fine condition of the ore resulting from concentration, and the Braden Copper Co. during the past winter installed three large kilns in Chile to nodulize the fine material obtained from oil concentration of the ore. One of these kilns has been in operation since early in the year and has proved the solution of a different problem.

The New Jersey Zinc Co., also, have employed a rotary kiln for nodulizing fine franklinite ore. From ore containing 17.1 per cent zinc, nodules containing 20.4 per cent zinc were obtained with little or no loss of metal.

The process of nodulizing does not differ very materially from other rotary kiln processes. The main point to be watched is the regulation of the temperature and the principal difficulties encountered are the sticking of the charge to the walls of the kiln.

BURNING LIME—In 1885, a patent was granted to Henry Mathey of New York, on a process of making lime which consisted "in first crushing the stone to a suitable degree of fineness, then burning the crushed or pulverized stone in a revolving cylinder, whereby the particles of stone are subjected to a constant and uniform heat." In the description of his process, Mathey proposed to crush the limestone to pass a No. 4 or 6 mesh screen, and to burn it in the rotary furnace which he invented and which has been described previously. Siemens also mentions the use of his rotary furnace for burning lime. I believe some experiments on burning lime in a rotary kiln were also made shortly after this at one of the cement plants in the Lehigh district, and also by the California Portland Cement Co.

In 1905 or 1906, the New York Lime Co. started to burn lime at Natural Bridge, N. Y., using a 100 ft. x 6. ft. rotary kiln fired by producer gas, and shortly after this rotary lime kiln plants were built by both the Union Carbide Co. and the Aluminum Ore Co. There are now in operation quite a number of rotary kiln lime plants, most of which, however, are supplying lime for chemical and metallurgical purposes for reasons given below.

An application of the rotary kiln to burning lime, of peculiar interest to the chemical industry, is the employment of the rotary kiln for burning lime from the waste carbonate of lime or "lime sludge" obtained from the manufacture of caustic soda by the action of lime on soda ash. Large quantities of this waste are produced by the paper-pulp manufacturers and also by caustic soda works. Lime-sludge is also produced by beet sugar manufacturers. The rotary kiln is now employed for burning waste lime from both industries. The rotary kiln is especially suited to burning these sludges as they can be introduced into the kiln in the form of a thin mud or "slurry."

Figure 7 illustrates a plant which the writer has designed for recovering the lime waste from the caustic soda department of a large soap factory. The water in the lime waste is reduced to the point at which the sludge can just be handled by a centrifugal pump or about 50% water. It is pumped in this condition directly into the kiln. The recovered lime comes from the kiln in small slightly oval balls and falls into a rotary cooler where it is cooled by a current of air. This latter is used for combustion and the lime in cooling preheats the air. The kiln is heated by a producer, the coal for which is fed from an overhead bunker.

For burning lime, producer gas is usually employed for heating

the kiln, but when great purity and absence of color are not required, pulverized coal can be used to advantage. The limestone to be burned is usually crushed to pieces of one-half inch and under, before being introduced into the kiln. The objection to the rotary kiln for lime burning is principally due to this latter fact. The lime produced is in the form of dust and small pieces, whereas for building purposes most users wish lump lime. This preference is due entirely to ignorance. Fine lime is usually the result of air slaking, and as air-slaked lime is partly carbonated, it is natural that

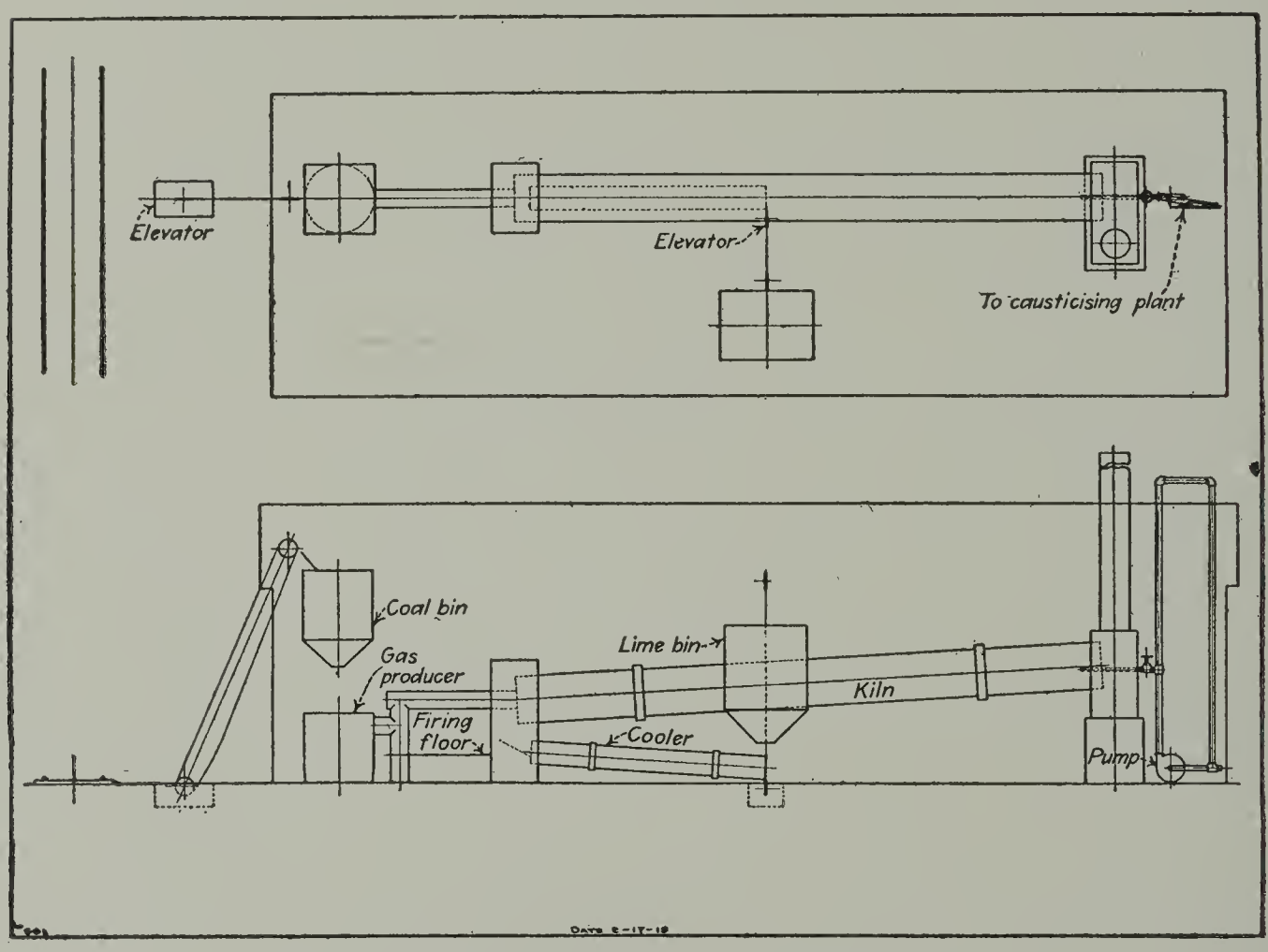


FIG. 7.—Plant for Recovering Lime Waste.

the builder should demand lime in lumps. On being supplied with rotary kiln lime, he supposes it is air-slaked lime and refuses it. Such lime, however, is particularly suited to metallurgical, chemical and agricultural uses, and to hydrated lime manufacture, for all of which purposes crushing of the lime is necessary.

The advantages of the rotary kiln are in its low labor cost of operating, the uniformity with which it burns if properly handled, and its high fuel efficiency. The labor item of lime burning can be cut in half by operating a rotary kiln and a fuel efficiency of six tons of lime for one ton of fuel has been obtained. For this reason

where lime is desired for chemical uses, for hydrate manufacture, for wood pulp plants, for fertilizer, and in short, where lump lime is not necessary, the rotary kiln will make lime cheaper than any other form of kiln. The first cost of a rotary plant is, however, 50 per cent greater than that of an ordinary grate-fired vertical kiln plant of the same capacity, but it is 25 per cent cheaper than a producer gas plant of like output.

One great advantage of the rotary kiln is the fact that small stone can be burned in it. It is also suited to burning stones which break up into smaller pieces and crumble on heating. Such stone cannot be burned in upright kilns because of the stopping up of the draft by the spalls.

A rotary kiln lime plant usually consists of a preliminary gyratory or jaw crusher for breaking down the big stone. This is followed by some form of break down mill or crusher to reduce the stone to pieces of ¼ inch in diameter and under. These secondary crushers are usually of the swing hammer type. The stone goes from the crusher to a bin, and from this is fed automatically and evenly into the kiln. From the kiln the lime drops into a rotary cooler where it is cooled. It is then elevated into a bin from which it is drawn for shipment as needed. At several lime plants boilers are installed at the ends of the kiln, making use of the waste gases from these to generate steam.

Roasting of Bauxite, Chemicals, etc.—Rotary kilns are now employed for drying and dehydrating many ores and chemicals. In 1902, a rotary kiln was installed for the dehydrating of bauxite, and this kiln has now come quite generally into use for this purpose. Producer gas is generally employed for heating such kilns, although oil or natural gas would be the most desirable fuel where either could be employed without too great expense.

A very high grade of ferric oxide pigment is now made in the rotary kiln by heating the residues obtained from spent pickling solutions. In this case, the salt has merely to be dehydrated, the sulfur trioxide driven off and the ferrous oxide converted to the higher oxide.

One large chemical company has a rotary kiln plant for dehydrating salts containing chemically combined water. The plant consists of four rotary kilns, each 120 feet long and 7 feet in diameter. Producer gas is used to heat the kilns and the exit gases from the kiln are passed through a dust collecting and washing apparatus

where they are scrubbed to recover valuable dust which they carry from the kiln.

The dust problem must always be considered in rotary kiln installations and where the dust represents a loss of valuable material or is likely to constitute a nuisance to the community, arrangements should be made to catch this dust. With small installations, a settling chamber and water sprays will prove satisfactory, but with large installations the problem is not so simple.

The rotary kiln, fired directly by a powdered coal, oil or gas flame, is one of the most economical methods of drying and dehydrating materials known. It is extensively used for drying blast furnace slag which has been granulated by water in the cement plants of the Universal Portland Cement Co. and would offer an excellent method of drying washed phosphate rock, ore, etc., where large quantities of very wet material are to be dried.

MAKING BICHROMATES—Mr. J. H. Payne, by employing a highly oxidizing atmosphere in the rotary kiln, has been able to produce sodium chromate, using this form of furnace in place of the reverberatory furnace now generally used for this purpose, and a patent has been granted him on this process.

BURNING PYRITES—Ducco, an Italian chemical engineer, in 1906 suggested the use of the rotary kiln for burning pyrites for the manufacture of sulfuric acid, the pyrites being fed in at one end and the air for combustion entering at the other. His first experiments on such a furnace were made in the works of Rifredi, near Florence, where the practicability of the scheme was demonstrated. Various other acid plants in Italy also use the rotary kiln for this purpose. As employed by Ducco, the internal surface of the kiln was provided with spiral grooves to facilitate the descending movement of the ore without the production of much dust.

In this country, the Pryite Engineering Co., Carthage, N. Y., are exploiting a system of roasting pyrites in a rotary kiln upon which they hold patents. They have installed such a kiln at the plant of the Hinckley Fiber Co., Hinckley, N. Y. This plant, at last accounts, was working successfully, burning an ore which sometimes ran as low as 20 per cent sulfur without employing any auxiliary heat. The pyrites is being roasted just as it comes from the ground, after being crushed to ¾ inch and down, using both lump and fines together. The lower end of the kiln is closed, a series of trap doors which work automatically allow the cinder to fall from the kiln

without the admission of too much air. When the kiln is first started, the pyrites ore is kindled by means of a jet of burning sulfur.

In view of the fact that the rotary kiln is much more simple than the ordinary mechanical rabble furnace, it is remarkable that more acid and pulp manufacturers have not given them a trial.

A novel use of the rotary kiln is in the production of sulfur trioxide. This process is in use at Höchst, at Hruschau and at Hamburg. Burnt pyrites, which has been soaked in ferrous sulfate solution, is passed into the upper end of a rotary kiln, the hot gases from the sulfur burners being admitted at the lower. The kiln (Fig. 8) is provided with shelves which pick the material up as the kiln

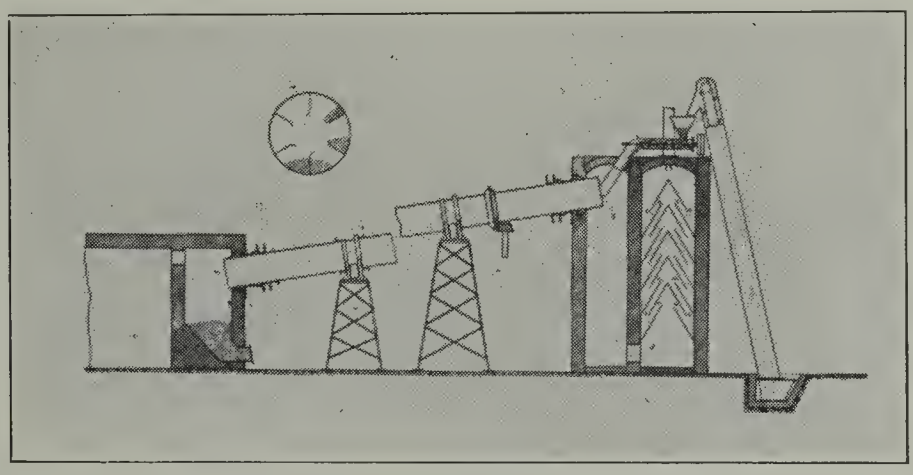


FIG. 8.—Rotary Tube Furnace for Manufacture of Sulfuric Acid.

revolves and cascade it in a spray of fine material through the current of gas passing through the cylinder. In the upper and colder part of the tube, the sulfur dioxide gas is absorbed by the burnt pyrites. As this works its way down through the cylinder to the lower end, the heat liberates all the sulfur dioxide in the form of vapors of sulfur trioxide and sulfuric acid. The gases are freed from dust and absorbed as usual. The burnt pyrite falls into a chamber at the lower end of the kiln and is reemployed by soaking in ferrous sulfate solution obtained from the treatment of pyrites containing copper.

MANUFACTURE OF SULFIDES—By designing the kiln so as to cut down the amount of air entering the firing end, it is possible to procure a reducing atmosphere in the kiln so that it can be used for the reduction of sulfates to sulfides. In this case, the problem is

a particularly easy one because of the low temperatures necessary in this work. Calcium and barium sulfate can both be reduced to sulfides with little trouble, using a grate fire to heat the kiln. Both are now made commercially in rotary kilns. Indeed, all of the more modern plants for the manufacture of barium sulfide are equipped with rotary kilns, and a large quantity of this compound is now produced and employed in the manufacture of lithopone blanc fixe, barium salts and in various chemical processes.

In manufacturing barium or calcium sulfide, the barytes or gypsum, as the case may be, is crushed and mixed with from 25 to 30 per cent of coarsely ground coal. The mixture is then passed through a tube mill or some other type of pulverizer where sufficient water is usually added to make of the powdered mixture a thin mud or slurry of about the consistency of thick cream. The pulverizing is carried to the point where at least 90 per cent of the mixture will pass through a 100 mesh screen. The slurry is then fed into the kiln in a regular stream, and as it works its way through the kiln, reduction takes place. Some of the sulfide formed, however, changes to carbonate.

The product obtained usually consists of from 60 to 75 per cent water-soluble barium sulfide, 20 to 25 per cent acid-soluble (chiefly barium carbonate) and 5 to 20 per cent insoluble. When the ore is pure and a good reducing flame is maintained, a reduction to 75 per cent of barium sulfide and only 5 per cent acid insoluble is obtainable.

The kiln is heated by a firebox with a hand-fired grate, one man being sufficient to fire the furnace and look after the kiln. The firebox should be designed to give a reducing flame and all joints should be tight so as to prevent excess air entering the kiln. A mechanical stoker would be the thing here. About 500 to 600 lbs. of coal per ton of barytes burned are required to heat the kiln and a similar quantity is mixed in with the barytes.

The red hot clinker from the kiln is usually conveyed immediately to the leaching tanks or other dissolving apparatus, where the sulfide leaches out very quickly. The insoluble is converted into barium chloride, unless it is high in barium sulfate, when it is refurnaced. The barium chloride solution is purified, filtered and concentrated to the point where this salt crystallizes out. The barium sulfide solution is filtered and stored in large tanks.

A rotary kiln 7½ ft. in diameter and 80 ft. long, rotating once

every 2 minutes, will furnace from 50 to 60 tons of barytes per 24 hours. Close supervision is necessary, however, and hence many plants operate only 10 to 12 hours per day. This is possible because of the low temperature employed and the ease with which the kiln may be heated up. The material furnaces easily and without complications.

Figure 9 shows the layout of a small plant for the manufacture of strontium sulfide which we have designed. The celestite and coal mixture are first crushed by means of a small rotary crusher, then elevated into a bin from which it is fed at a regular rate to a small Raymond pulverizer where it is ground to nearly all pass a No. 100 screen. From the pulverizer it goes to a bin and from this is fed into the kiln by means of an automatic feeder and a paddle conveyor. A water spray located over the latter moistens the powder. The reduced material is caught in barrows and the kiln is heated by a grate fire using coal as fuel.

AGRICULTURAL CHEMICALS—When phosphate rock is mixed with from 15 to 20 per cent of certain alkaline fluxes such as the sulfates, carbonates and nitrates of the alkalies, finely ground and heated in a rotary kiln to the point of incipient fusion, a sintered mass is obtained in which practically all of the phosphoric acid is present in a form soluble in ammonium citrate solution. Numerous patents have been granted covering such processes, but the basic principle was made known by Baskerville in 1898, and Wiborgh obtained a patent upon essentially this process the same year. The product is analogous to Thomas slag, which is highly recommended as a source of phosphoric acid for plant food.

The process is commercially possible, but the low price at which sulfuric acid has been obtained as well as the fact that the demand has been greatest for a water-soluble and not a citrate-soluble phosphate and the conflicting claims of the various patentees have all tended to retard the application of the process on a large scale.

The reaction whereby the potash can be made water-soluble by ignition with calcium carbonate and ammonium chloride is familiar to all analysts, as it is the basis of the determination of this element in silicates. The proposal has been made to ignite a finely ground mixture of limestone, calcium chloride and feldspar in a rotary kiln and thereby obtain a product in which the potash is soluble. The proposition has also been advanced to make white Portland cement from a mixture of feldspar and limestone, both practically

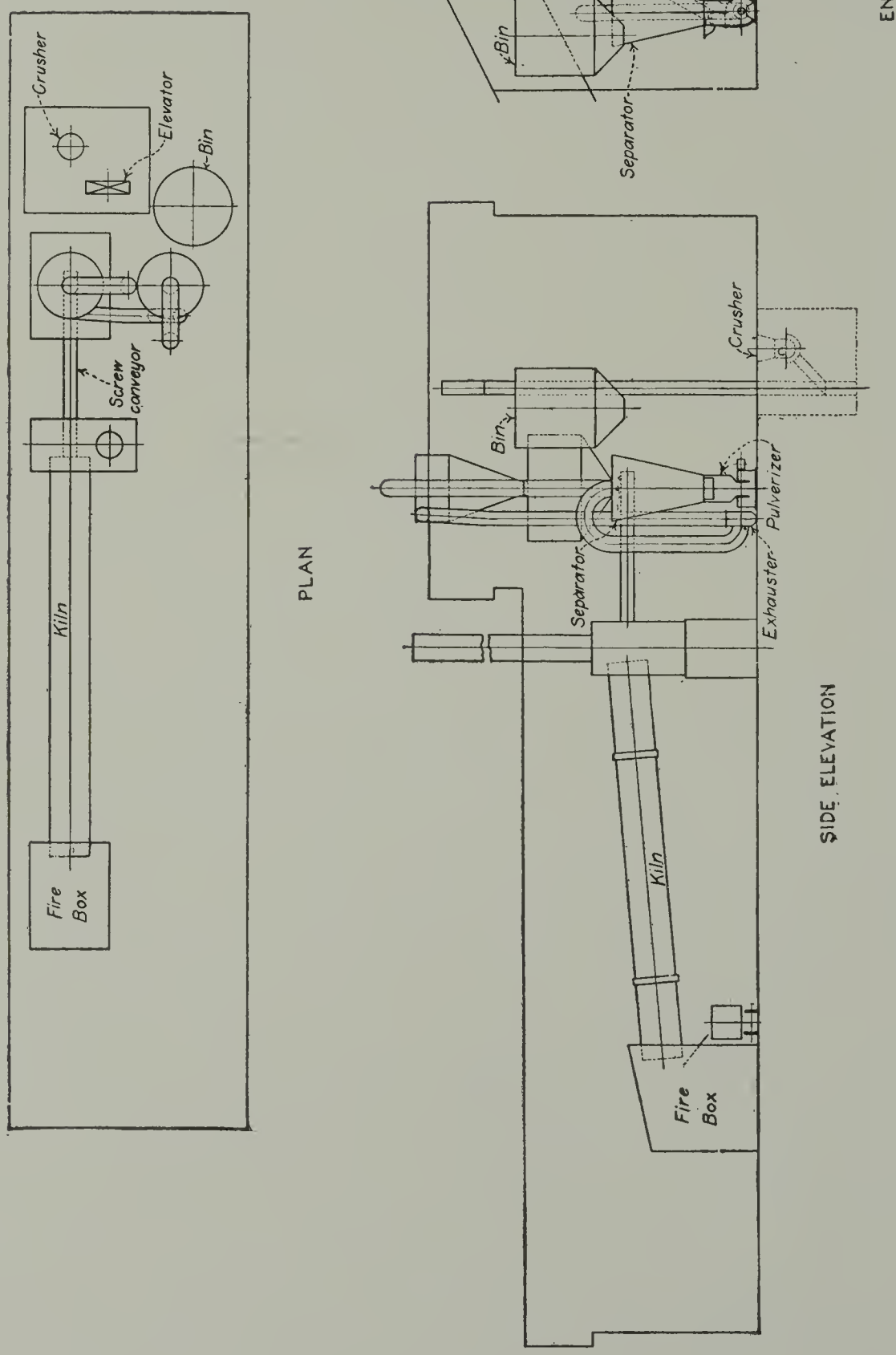


FIG. 9.—Plant for the Manufacture of Strontium Sulfide.

free from iron, and obtain potash as a by-product, the latter being volatilized at the high temperatures employed in the cement kiln.

The first proposition for potash does not seem to promise much, because of the small percentage of potash obtainable in the product —only about 3 or 4 per cent—and its consequent low value. With the second process the problem of catching the potash presents considerable mechanical difficulty.

Both the process for rendering phosphoric acid citrate-soluble and that for obtaining a potash-bearing material from feldspar have been the subjects of extensive experiments, some of which have even gone so far as trials with a full-size rotary kiln, and practically all of the large manufacturers of agricultural chemicals have looked into the subject. In view of the possibilities of both processes and the heavy and sure demand for such chemicals, these processes present an attractive problem for research.

We have a small rotary kiln 20 feet long and 2 feet in diameter. In this we have been able to burn from mixtures of lime, soda-ash and phosphate rock, material running as high as 26 per cent citrate-soluble P_2O_5. This experimental kiln is large enough to approach very nearly plant conditions and any results which we can obtain here should be easily obtainable in a large kiln.

FUTURE APPLICATIONS—In conclusion, we might say that the rotary kiln seems to us peculiarly adapted to certain chemical processes, and where it can be employed, will usually be found the most economical form of furnace, for the following reasons:

1. The rotary kiln can be operated with far less labor than other furnaces. Over upright shaft furnaces the saving amounts to from 50 to 60 per cent, and over reverberatory and hearth furnaces from 50 to 75 per cent. One skilled man with the assistance of a laborer at the feed end, who also attends to the oiling, can easily look after two 8 x 125 ft. rotary kilns.

2. The upkeep of the rotary kiln is less than that of any mechanical furnace. The lining, of course, on some materials, is subject to destruction from the scorifying action of the charge, but outside of this the repairs and renewals amount to almost nothing. Mechanical repair on an average amount to $2.00 per day for an 8 x 125 ft. kiln. There are no rabble arms to break, and no metal parts are subject to corrosive gases.

3. The power required to drive the kiln is much less than that

needed for any mechanical furnace of similar capacity. The power required for the above size kiln amounts to about 20 H.P.

4. Its continuous action promotes fuel economy and large outputs per unit. No time or fuel is lost in heating up and cooling down the kiln as with intermittent furnaces, and the steady flame of the jet of burning powdered coal gives a much more uniform temperature than is possible with furnaces which are fired by hand, and hence into which cold air is continuously entering when the fire is stoked. The fuel saving of the rotary kiln over a reverberatory furnace amounts to from 30 to 50 per cent.

5. Wet materials may be furnaced as well as dry, the upper part of the kiln acting as a drier, and both fine material and lumps may be burned at the same time.

6. The charge is at all times under control and is advanced regularly through the kiln at the desired rate. This rate may be changed at will by quickening or retarding the speed at which the kiln revolves.

7. High temperatures may be obtained and any fuel desired employed. Both oxidizing and reducing flames may be secured.

As to the processes to which the rotary kiln is most applicable, these would seem to us to be:

1. Processes in which carbon dioxide, combined water or other volatile constituents are to be driven off by heat and at temperatures below 2700° F.

2. The oxidation of ores, chemicals, etc., whether this is accompanied by burning of sulfur or other combustible elements or not.

3. The reduction of compounds where this can be accomplished by heat in a reducing atmosphere either with or without the use of a reducing agent. The kiln is particularly suited to reducing processes where these consist in mixing a reducing agent with the compound to be reduced and the mixture finely ground and furnaced.

4. Processes which consist in the formation of new compounds by partially fusing or sintering a mixture of two or more materials.

5. Processes which are designed to merely change the physical state of a substance by just heating the material (either alone when fusible or with some fusible binder when not itself fusible) to the point when the particles cohere to the form nodules or clinker of the desired size.

Two or more of the above processes are often carried out in the same furnace, as for example, in the manufacture of Portland

cement, where the carbon dioxide is first driven off and then the silicates and aluminates of lime are formed.

The rotary kiln is not suited to reactions which are attended with marked fusion of the material, that is, when the mass must become fluid before or in order for the reaction to take place. When the fusion takes place above the temperature at which the reaction is completed, the rotary kiln may be employed with proper care to control the temperature. Where only sintering takes place, the kiln, of course, gives entire satisfaction and many reactions which ordinarily require fusion of the mass to take place may be carried out completely without having the mass either molten or even pasty, by simply grinding the components finely and heating only to the point of incipient fusion or sintering. Here the greater surface exposed allows the reaction to take place by diffusion. Examples of this are found in the process of making available phosphoric acid referred to above, and also in the burning of cement clinker.

202 North Calvert Street,
Baltimore.

A COMBINATION WATER SOFTENER AND STORAGE TANK

By L. M. BOOTH

Read at Troy Meeting, June 20, 1914

Any water purification process implies that the purified water is to be used. How best to store this water between the time it is purified and used is a matter for consideration. In some industrial plants, the rate of use of water is fairly constant throughout the day, and the water is used as fast as it is softened and no storage is necessary. Most water users, however, have one or more considerable peaks in their load requiring the delivery of large volumes of purified water during a short space of time. The usual plan has been to provide a separate tank or reservoir.

During the past ten years a great many softeners equipped with excelsior filters, affording softened water storage capacity for one hour's flow (more or less)—sufficient for ordinary requirements of an industrial or power plant—have been built. This storage capacity is provided by slightly increasing the height of the tanks above the filter, to gain the desired volume. A softener arranged to include storage capacity above the filter is shown in Figure 1.

This provision for storage capacity, while adequate to serve the needs of most power plants, necessitates the use of raw water for perhaps half a day, twice each year, in order to provide opportunity to change the filtering material. To use raw water, supplied directly to the feed water heater for boiler feed, for such a brief interval, is not especially objectionable. For railway water stations, however, such a plan has very little to commend it, because during the periods of filter cleaning, there is no water available, stored at sufficient height, to fill a locomotive tender in the usual short period.

The best water softening practice in vogue at the time the first modern water softeners were imported from Europe, late in the nineteenth century, called for the use of filters to clarify the

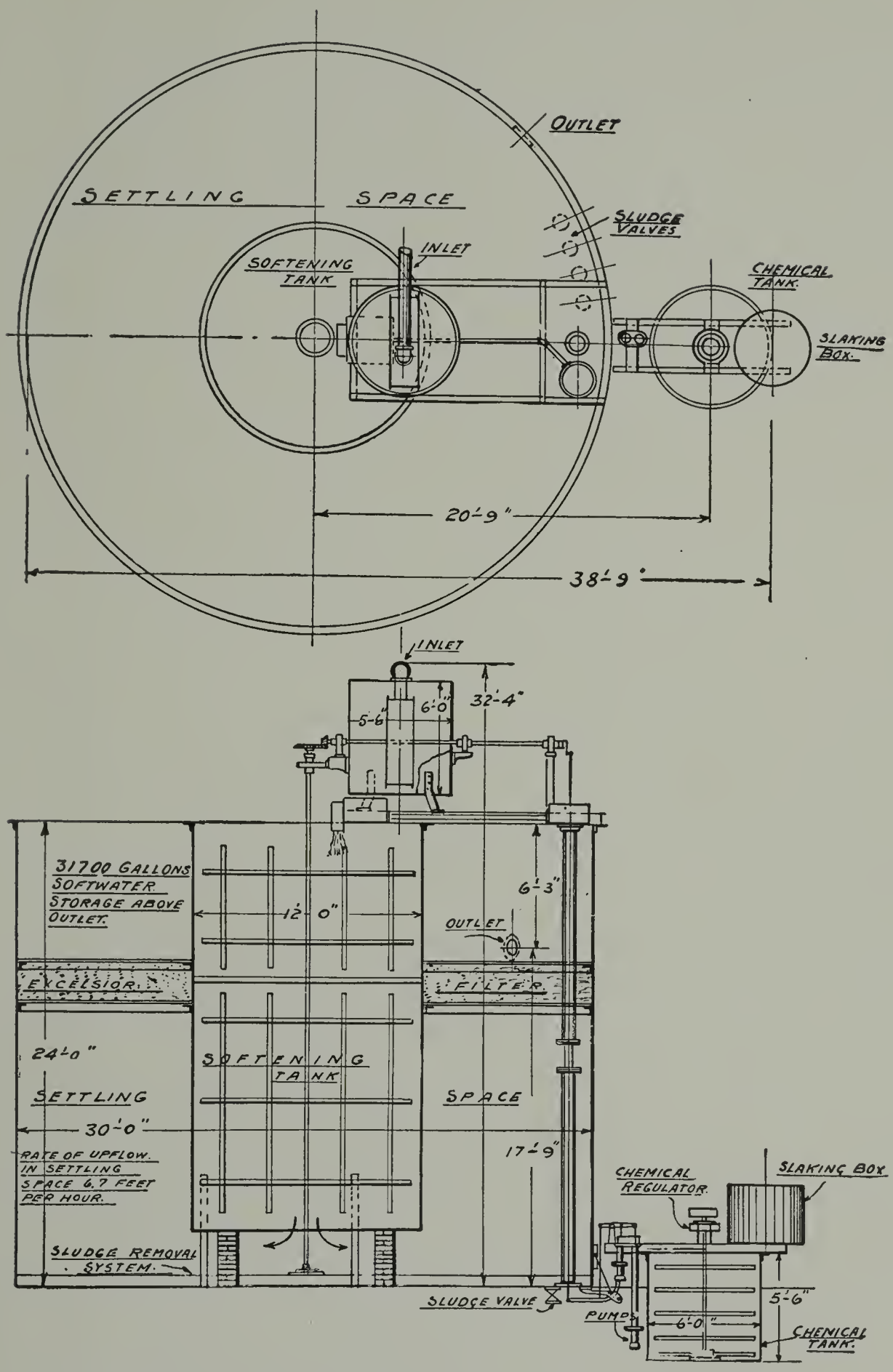


FIG. 1.—Booth Water Softener, 30,000 gallons per hour.

Dayton Power & Light Company, Dayton, Ohio

imperfectly settled water. Usually these filters were constructed of "excelsior" (wood shavings). Careful observations of softeners operated at a small fraction of the rated capacity—corresponding to more liberal design—readily demonstrated that if the rate of upflow in the settling space were restricted to a very slow flow, practically no suspended matter reaches the filter. By gradually adopting more liberal standards of settling tank design, the point is soon reached when the expense of installing and maintaining a filter is not justified, for purifying boiler feed water.

After demonstrating that the filter is not an essential feature of water softener construction, it becomes a simple problem to add any reasonable amount of pure water storage.

As a result of several years practical experience and study, having in mind the possible elimination of the filter, the softener at the foundry of The National Malleable Castings Company, Toledo, Ohio, as shown in Figures 2 and 3, was designed and installed to soften and clarify the hard and sewage laden, muddy Maumee River water for boiler feed.

More rapid progress toward the development of the "No-Filter" softener for purifying boiler feed water would have been possible except for the popular prejudice favoring the use of a filter of some kind. The average individual cannot conceive how it would be possible to simplify and improve a softener by omitting the filter. Several of these "No-Filter" installations having been made, and having demonstrated their fitness to meet requirements, the construction of a "No-Filter" softener equipped to store purified water, has become a commercial proposition. A typical installation of this kind is shown in Figure 4.

Somewhat more than the upper half of this tank, which is 40 feet high, is devoted to the storage of softened water. Figure 5 shows the general arrangement of this softener.

The water enters at the inlet and passes to an over-shot water-wheel which furnishes the power to drive the agitator in the chemical tank at ground level as well as the agitator in the softening tank. The same source of power also operates the chemical feed pumps. One of these pumps delivers the chemical solution to the chemical regulator located on the chemical tank, and the other elevates the solution which has been measured by the chemical regulator, to the top of the softening tank, where it meets the raw water which has passed over the water-wheel.

The down-flowing water and chemicals are thoroughly mixed in this softening tank, during a period of twenty-eight to forty-eight minutes, depending on the amount of water in the storage space. When operated at less than the rated capacity of 50,000 gallons per hour, the time of flow is proportionately longer.

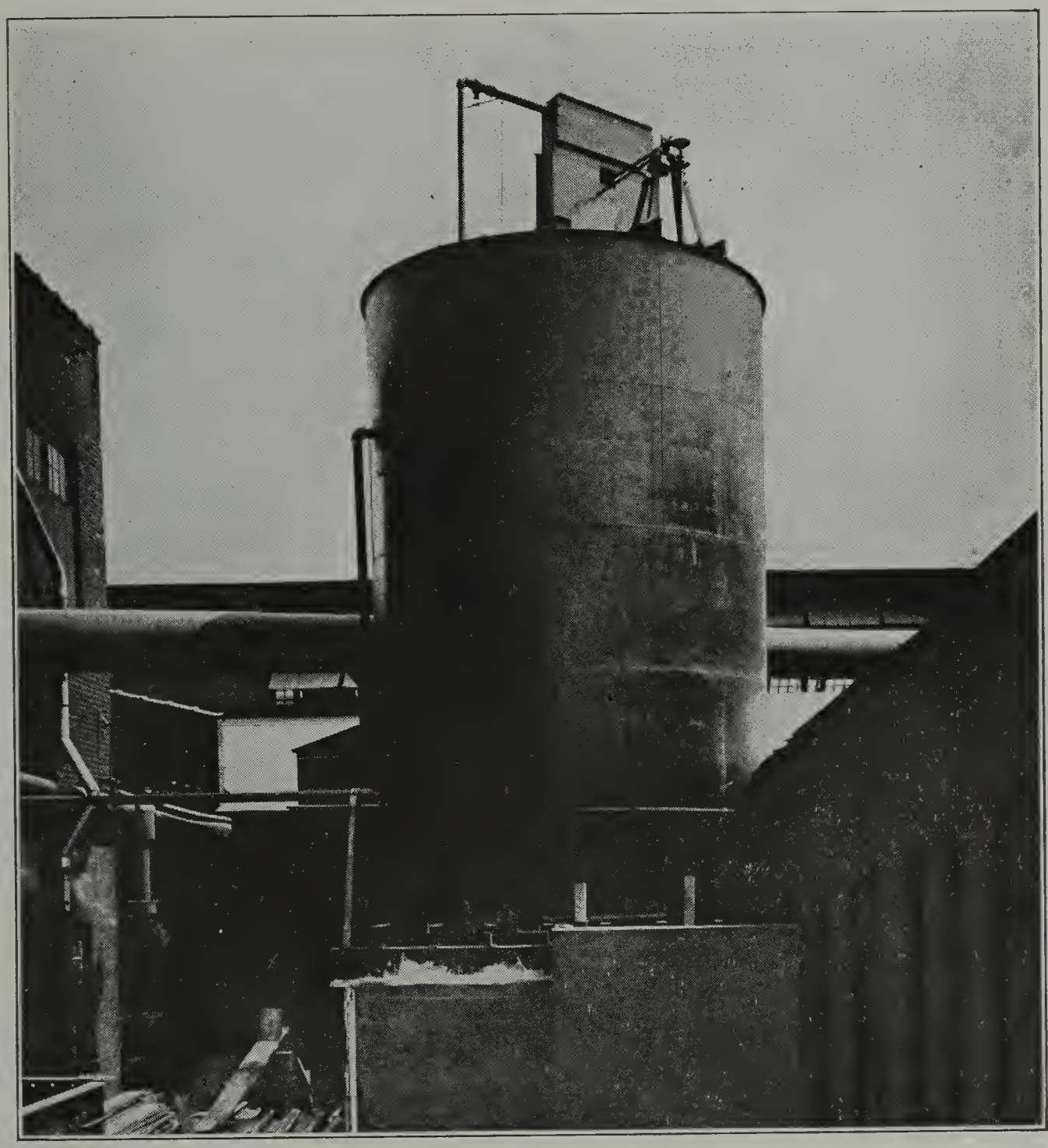


FIG. 2.—Booth Water Softener, 5000 gallons per hour.
The National Malleable Castings Co., Toledo, Ohio.

The action of the softening tank mechanical agitators in preparing the precipitate for sedimentation is described below and is shown in Figure 7.

In the design of each of the softeners described, the two im-

portant functions of water softening, namely, the formation of precipitates and their later sedimentation, have had individual attention. These functions are as diverse as their natural tendencies,

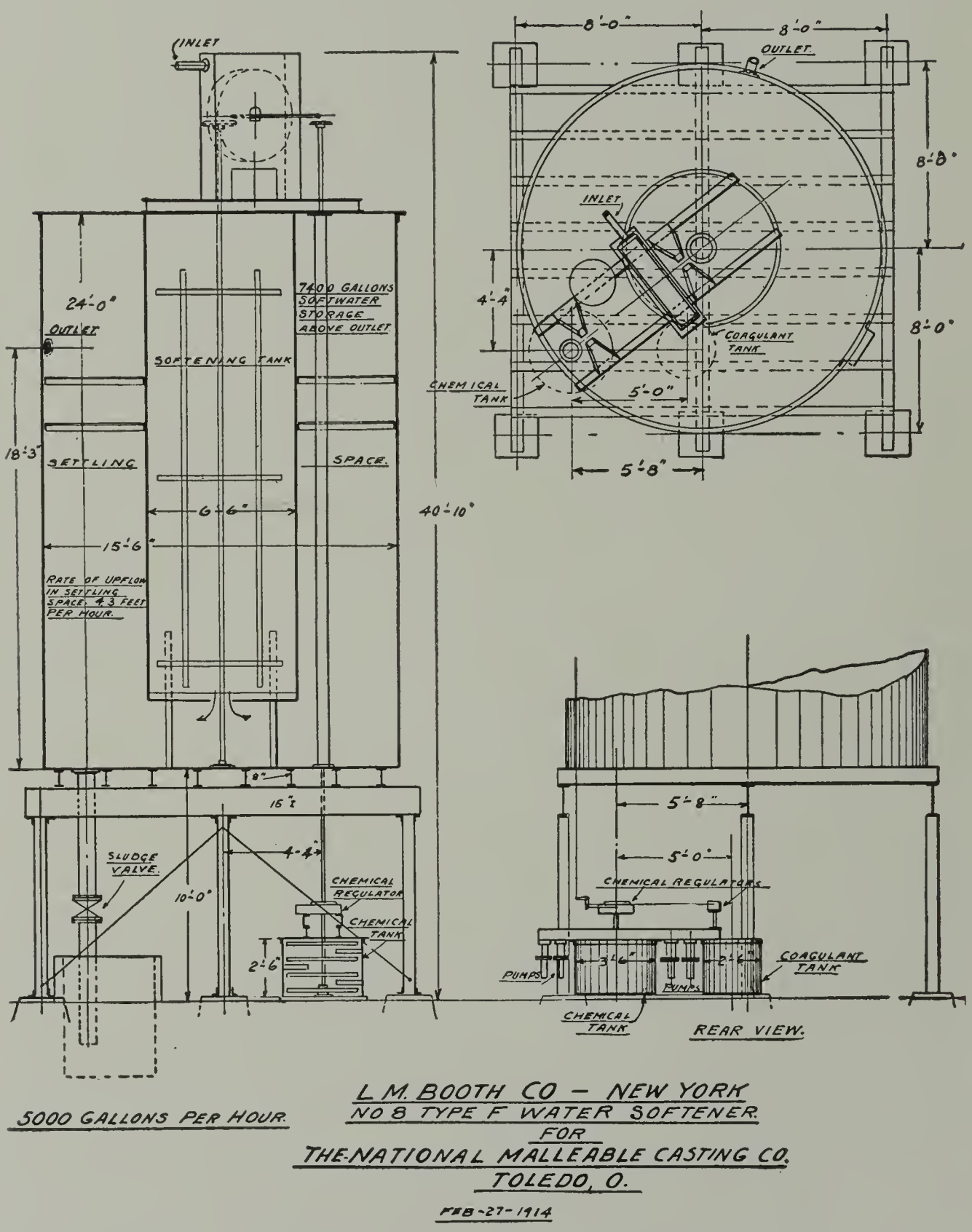


FIG. 3.—Booth Water Softener, 5000 gallons per hour.
The National Malleable Casting Co., Toledo, Ohio.

which are motion and rest, respectively. Due consideration must be given these distinctions in designing an efficient water purification plant.

During the softening reaction, the movement of molecules plays an important part, and requires a thorough mingling of the purifying reagents with the hard water. The water is, therefore, subjected to mechanical agitation, in the softening or reaction com-

FIG. 4.—Booth Water Softener, 50,000 gallons per hour.
Chicago, Rock Island & Pacific Railway, Burr Oak, Ill.

partment, until the precipitate is not only well under way chemically, but also well formed physically.

From the softening tank, the water flows upward through the settling space at a rate of 3.61 feet per hour, which is sufficiently

slow to effect clarification of this particular water. The time of flow from the bottom of the softening tank to the outlet is 4.4 hours when the softener is operated at rated capacity.

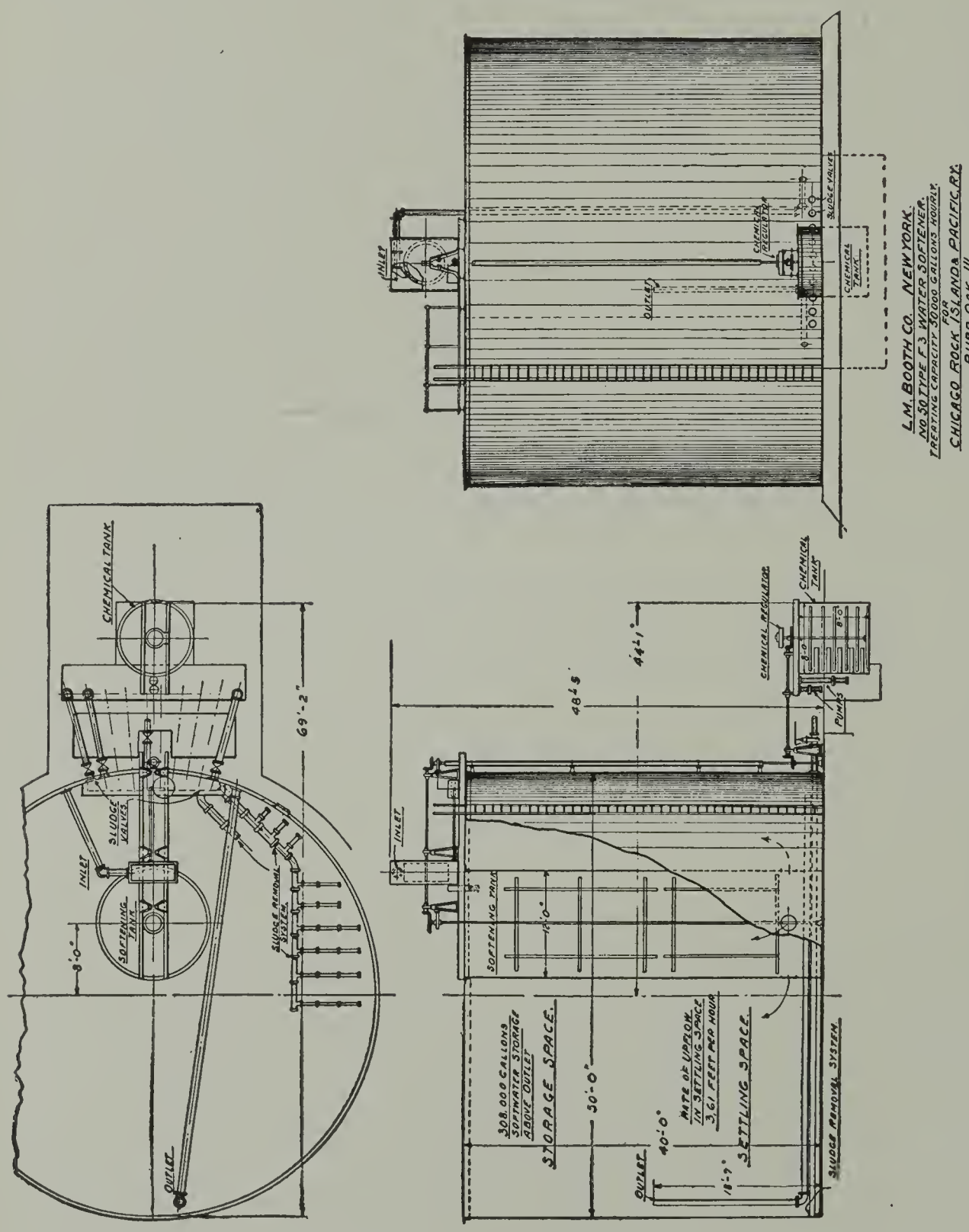
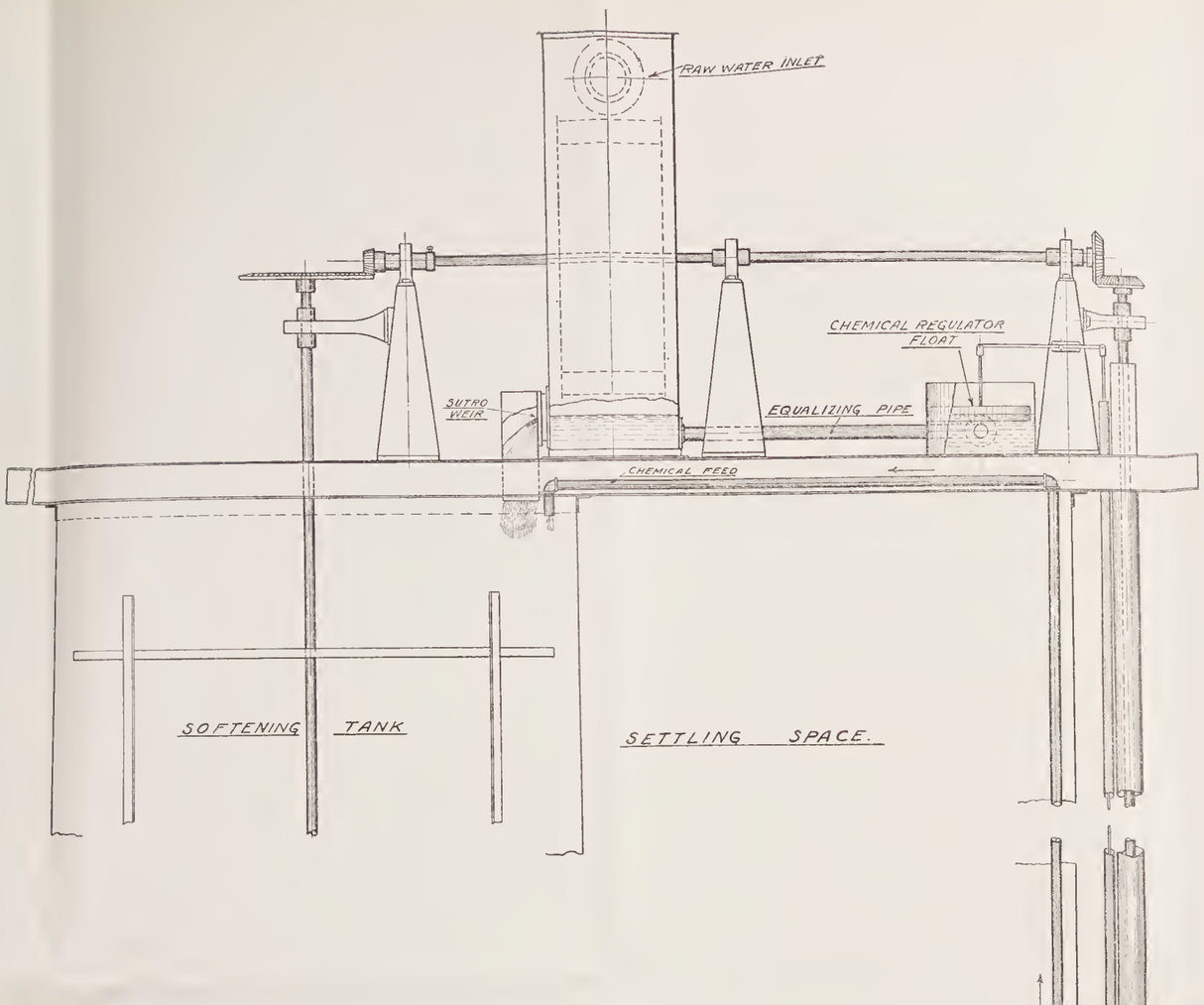
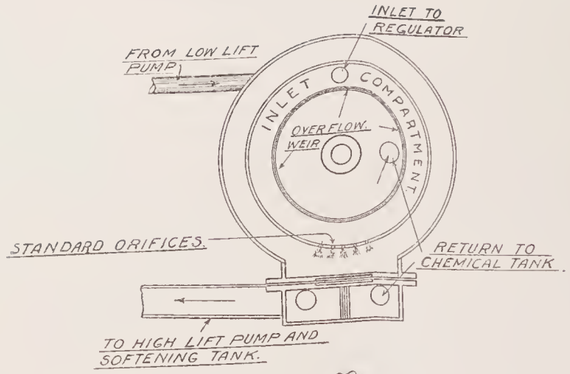


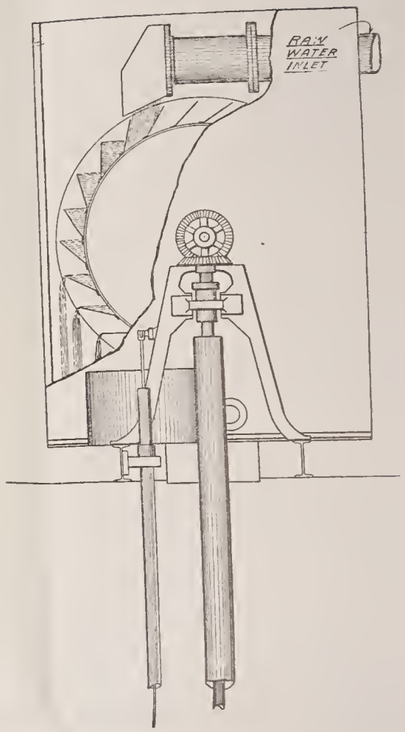
FIG. 5.—Booth Water Softener, 50,000 gallons per hour. Chicago, Rock Island & Pacific Railway, Burr Oak, Ill.

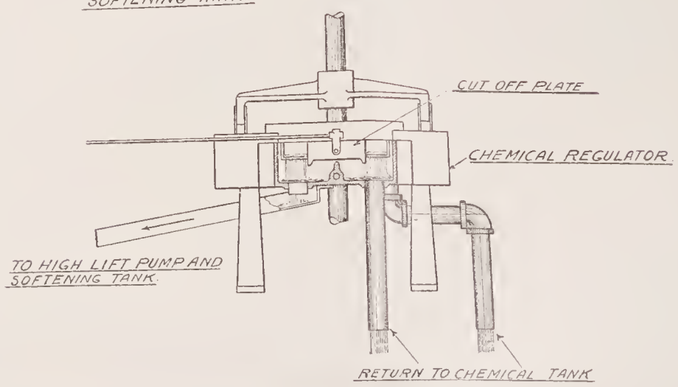
There is available for immediate use, 308,000 gallons of softened water above the outlet when the storage space is full. This volume is sufficient to meet the demands of a large locomotive terminal and freight yard.

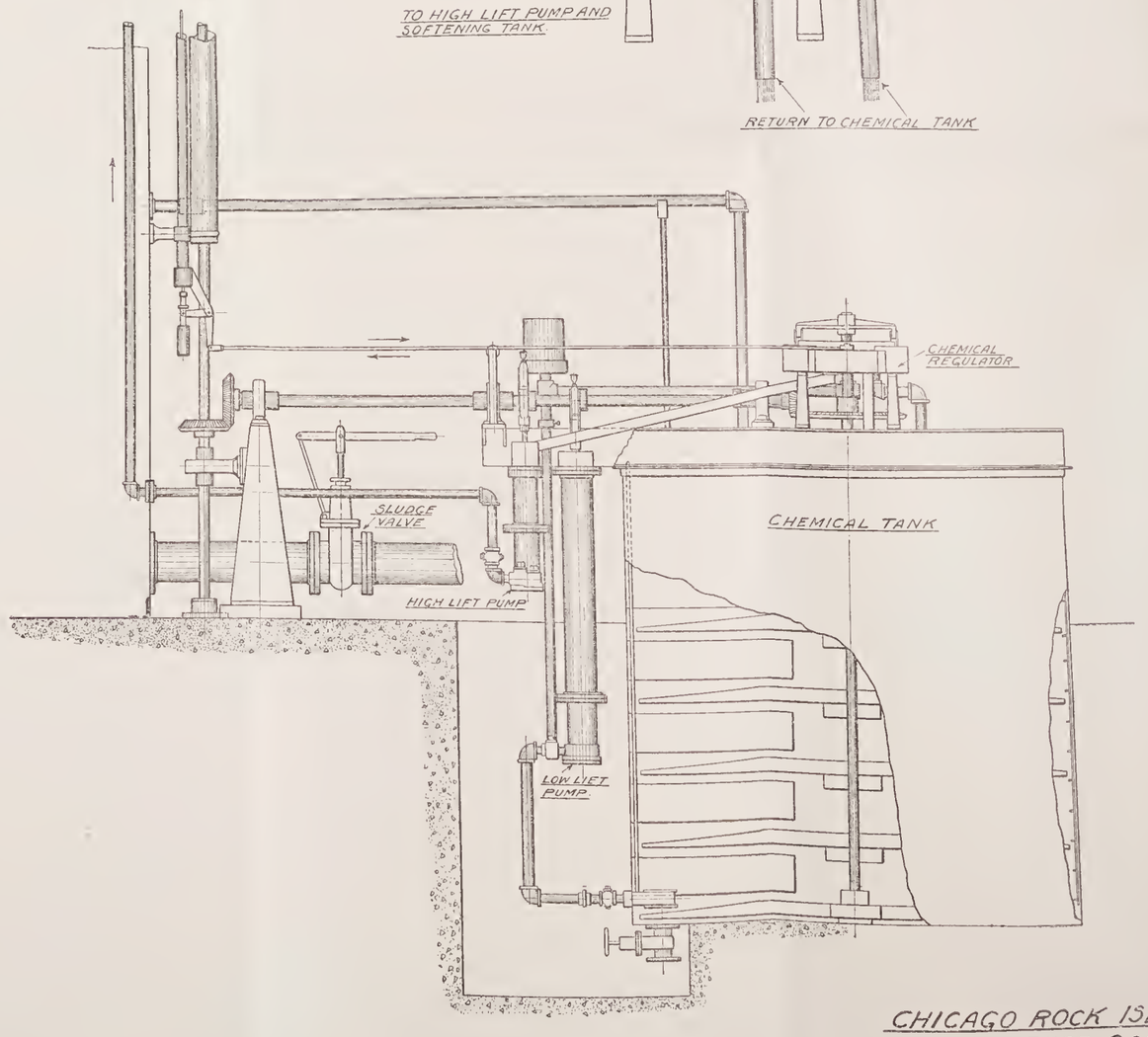
Figure 6 shows in detail the manner of handling the chemical solution. The reagents used are hydrated lime and soda ash.

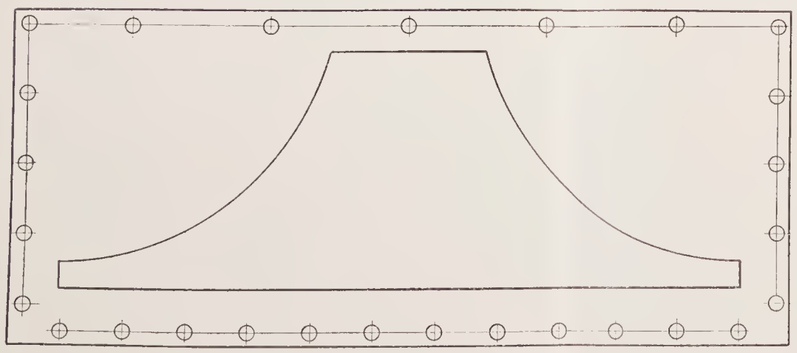












SUTRO WEIR

CAPACITY 50,000 GALLONS PER HOUR.

CHICAGO ROCK ISLAND & PACIFIC RY.
BURR OAK, ILL.

MAY-14-1914

Fig. 6.—Details—Booth Water Softener. Chicago, Rock Island & Pacific Railway, Burr Oak, Ill.

The low lift pump takes its suction through a strainer screen near the bottom of the chemical solution tank. The solution is delivered to the inlet compartment of the chemical regulator, mounted on the chemical tank. The level of the solution in this compartment is maintained at constant height, for the reason that sufficient solution is delivered into it, to keep the solution continually overflowing the inner weir. The excess solution returns to the chemical tank. An uniform flow of solution, sufficient to treat 50,000 gallons of water per hour, from the inlet compartment, flows through the standard orifices, which are always under a constant head. When the softener is run at full capacity, all of this solution is required; but if, for instance, it is operating at one-half capacity, as shown in the detail view of the chemical regulator, only one-half of the maximum flow of solution passes down the feed chute to the high lift pump, by means of which it is delivered to the softening tank. The other fifty per cent, which passes the cut-off plate on the other side, returns directly to the chemical tank. Similarly the feed is directly proportional to the amount of water entering the softener for all other rates of flow. The chemical regulator cut-off plate is actuated and controlled by a float riding in a tank supplied with water which has passed over the water wheel. The varying heights of water in the lower part of the wheel box are transmitted to the float tank through an equalizing pipe.

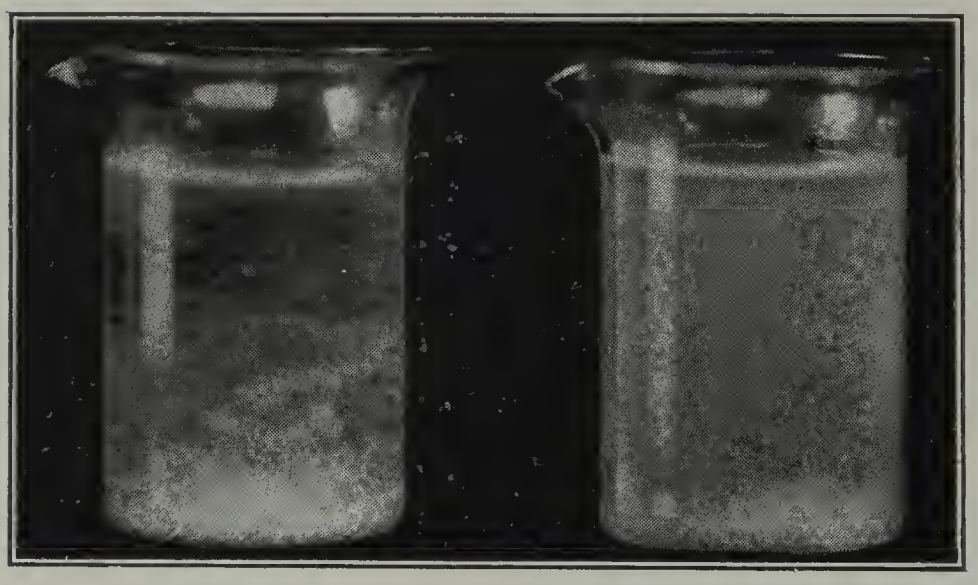
The outlet for the hard water from the wheel box, into the softening tank is through a Sutro weir, the general shape of which is shown in the detailed view. The extreme width of this weir opening is 25 inches. In view of the fact that the height of the water flowing through the Sutro weir is at all times directly proportional to the quantity, it will be seen that the vertical movements of the regulating float are always proportional to the quantity of water flowing. The vertical movements of this float are transmitted by means of a lever, links, and bell crank to the cut-off plate of the chemical regulator and thus control the proportional feeding of the chemical solution.

The Sutro weir is a liquid measuring notch of such shape that the quantity of liquid discharged is at all times in direct proportion to the head of water above the crest of the weir. In other words, for any given Sutro weir the discharge is proportional to the first power of the head rather than to some fractional or multiple power thereof, as is the case with every other form of weir. This weir,

however, is to be distinguished from other proportional-flow weirs which have the form of a parabola, and theoretically must be of infinite width at the base; the latter type being of no practical value.

The inventor, the late Harry H. Sutro, based his patents, the first of which was issued November 4, 1913, upon a shape which compensates for all discrepancies which would interfere with its value in the practical operation of a weir type of meter.

Aside from a liberal design of settling tanks, there is one other important feature of this type of softener which materially assists the settling tank to deliver a clear water. This is the provision for mechanical agitation in the softening tank. The agitation is continued sufficiently long, not only to thoroughly distribute and mix



a *b*

FIG. 7.—Softening experiments at the end of three minutes. Stirred, *a*, and unstirred, *b*.

the chemicals with the water, but also to insure coagulation of the precipitate, so that it will settle promptly, as soon as the quiet condition of the settling tank is met.

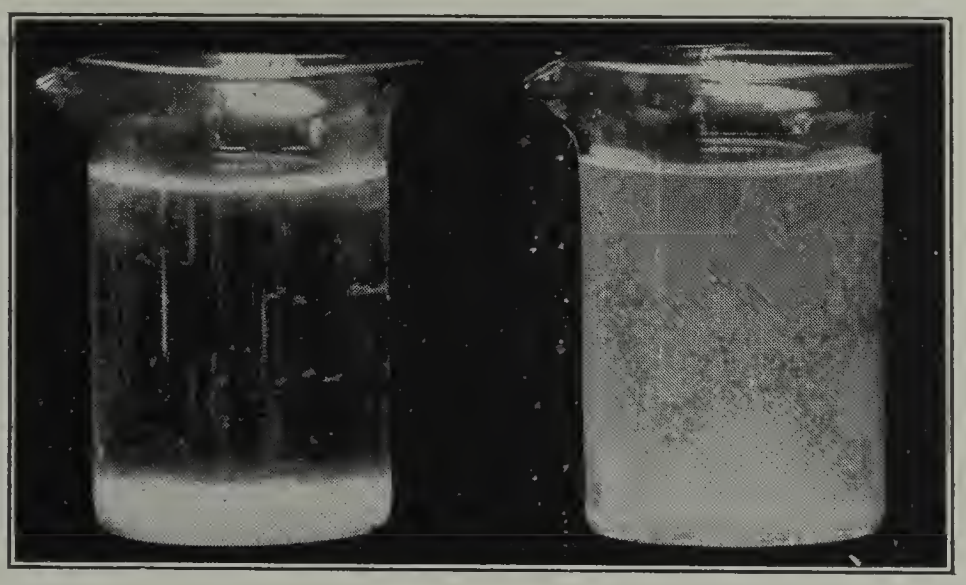
Figure 7 is an example of the influence of mechanical agitation, as compared with another softening experiment similar in all respects, with the exception that only a slight mixing was given in 7-*b*, the "unstirred," whereas, 7-*a* had been subjected to the kind of agitation which experience has shown to be the most efficient for precipitates of this kind.

Photograph (Figure 7), was taken at the end of three minutes following the addition of chemicals at the rate of 1.9 lbs. of lime and 1.2 lbs. of soda ash per thousand gallons. The raw water in

this case had a hardness of 285 and an alkalinity of 235 parts per million, corresponding in grains per U. S. gallon to 16.6 and 13.7, respectively.

In the experiment with sample *b* there was only a slight mixing of the water caused by eight revolutions of the agitator, whereas sample *a* was stirred for three minutes, at the end of which time the preciptiate had become fairly well coagulated. The slight blur in sample *a* shows that while the stirring had ceased, the precipitate had not yet come to rest.

Figure 8 shows the same samples, neither of which has been touched since the first photograph (Figure 7) was taken. The second photograph shows the difference at the end of six minutes,



a *b*

Fig. 8.—Softening experiments at the end of six minutes. Stirred, *a*, and unstirred, *b*.

by which time the precipitate in sample *a* had almost completely settled, whereas sample *b,* as may be noted, shows its precipitate to be very much behind in development.

These simple experiments demonstrate clearly the advantage gained by the proper kind of mechanical agitation while the precipitate is in process of formation. As already stated, mechanical agitation plays an important role in the "No-Filter" softener, which makes feasible the storage of a large volume of softened water in the same unit with the softener.

Some of the advantages of this softener are:

1. All handling and regulation of chemicals is accomplished at ground level.

2. Mechanical agitation for the softening tank is provided.

3. There is sufficiently slow upward flow in the settling space to deliver a clear effluent.

4. Convenient arrangement of storage capacity.

The combination of the softening and storage features results in a saving of ground space as well as in cost of the plant. No separate foundation is necessary. It is an important advantage that the water is stored at a considerable elevation, suitable for delivery without pumping to feed water heater or locomotive tender.

This type of plant is particularly well adapted for railway water station use. In this service, where the stations are frequently isolated and not closely supervised, the simplicity of construction is especially desirable.

DISCUSSION.

PRESIDENT: This interesting paper of Mr. Booth's is open for discussion.

Mr. SCHROEDER: I would like to ask Mr. Booth, if, in his experience with these plants, he has found any more difficulty in controlling subsidence of the precipitated matter in smaller outfits than in the one just described, and at the same time to readily obtain a clear effluent with steady draft.

Mr. BOOTH: As we understand sedimentation, two facts are important, first the character of the precipitate and the next is the rate of upflow. If you can maintain the rate of upflow at so slow a speed that you wouldn't get any precipitate, you get clear water.

Mr. SCHROEDER: Then does it not compel you to hold back in storage, a certain large volume of water beyond that which may be required within a given period, before your clear effluent is assured?

Mr. BOOTH: In this instance, the period of retention in the settling space, above the outlet, is nearly five hours. In this case, the outlet is 18′ 7″ high, and the water travels at a rate of less than 4 feet, vertically per hour. I would not recommend cutting down of the sendimentation period unless the rate of upflow can be decreased. On the other hand, if the outlet must be placed at a higher point, the period of retention in the settling space must be increased, in order not to unduly increase the rate of upflow in the settling space.

Mr. SCHROEDER: It appears to me that you might have trouble in smaller tanks from circulating currents tending to prevent complete sedimentation before drawing off, unless you depend on providing tanks nearly twice the height necessary for holding the quantity of water available for use.

Mr. BOOTH: The efficiency of a settling tank is in general directly proportional to its flow area, namely, the net cross section. In designing settling tanks, it is the aim to restrict the rate of upflow to such a slow rate that circulating currents, except those set up owing to a rapid change in the temperature of the water, have no disturbing influence. Temperature changes are not within the designer's control. For instance in some industrial plants, where hot water is supplied for treatment on certain days of the week, there is a "turnover" of the water when the hot water is again used, after the Softener has been filled with cold water. This experience is the same as is met with in the operation of large Water Works Sedimentation Reservoirs.

Mr. SCHROEDER: This paper has been particularly interesting to me on account of an experience I had about two years ago with a treatment and filtration system which included a 500,000 gallon storage tank in which, on account of faulty arrangement of the system, I found most of the sedimentation taking place in the tank, leaving nothing for the filters to do but take out the suspended matter.

I, therefore, decided to cut out the filters and try using the tank for clarification, giving time for sedimentation by using a 16-ft. riser inside the tank.

This served the purpose very well, but I was not allowed to sacrifice so much of the capacity of the tank, it being necessary at times to take water from below this level.

FELDSPAR AS A POSSIBLE SOURCE OF AMERICAN POTASH

By ALLERTON S. CUSHMAN and GEORGE W. COGGESHALL

Read at the Philadelphia Meeting, December 2, 1914

Two years ago the authors presented a paper before the Eighth International Congress of Applied Chemistry, entitled "The Production of Available Potash from the Natural Silicates." This paper, which was printed in the Transactions of the Institute, Vol. V, 1912, not only presented a general discussion of the work that had been done by a great number of investigators in this field, but also described the results of practical mill runs made by the authors on the large scale of operation. This work had been carried to a successful conclusion as far as the purely chemical engineering side of the problem was concerned, but for reasons which seemed important at that time, no presentation or analysis of cost data was included in the first publication.

As a rule, no worker is in general so much hampered by complex commercial situations in his particular field as the chemical engineer, and this is particularly true with respect to potash problems which rest more or less insecurely upon a net-work of local, national and international regulations, economics, and special arrangements. The prices of crude and finished potashes have not in the past rested on the firm basis of cost of production and transportation, modified by the just law of supply and demand, but have been subject to unstable arrangements between national governments and international syndicates. The governments of great nations make bad partners for industrial enterprises in these uncertain days, for they themselves seem to be unable to guarantee the validity of their own contractural agreements. Furthermore, the fixing of prices of a necessity of industry and agriculture by international or national syndicates, by which the interest of the ultimate consumer cannot be a prime consideration, is utterly opposed to the present day tendency in the development of human affairs.

It is one thing to work out a complicated problem in chemical engineering to a successful technical working status on an encouraging basis of costs, but it is quite another thing to assume the responsibility of inducing capital to embark upon an unknown sea of enterprise, especially if this sea is strewn with uncharted rocks and shoals, one, at least, of which may represent the cutting of prices by foreign producers to or below the cost of production for a sufficient period to kill off new born competition, with the idea of averaging up profits at some future time when the infant industry shall have been effectually strangled. As chemical engineers, however, we may take some comfort for the future from the thought that such premediated arrangements are becoming unfashionable if not dangerous.

It is the purpose of this second paper, which may be considered an elaboration of our earlier publication, to present the results of some additional investigation, together with a frank discussion of the cost data involved in the possibility of using American feldspars as a practical source of American potashes. Many workers in this field believe it to be a self-evident fact that the potash alone would not pay the cost of extraction, or, in other words, unless the potash yield was merely a by-product recovery in the manufacture of some valuable main product, the attempt to extract it would be foredoomed to failure. After having made a close study of certain phases of this problem, continuing over a period of many years, we wish to state that in our opinion, the economic feasibility of turning to the feldspars as a source of potash is, to say the least, open to debate. Feldspar can be obtained in unlimited quantity favorably situated to our freight and trade routes in this country, which will run quarry-wise ten per cent in potash (K_2O). The raw material supply, as far as potash ore is concerned, resolves itself therefore into a mere question of economical quarrying operations at the usual well-known costs. A comparatively small quarry of such feldspar, containing 1,000,000 cubic feet of rock, or 100 feet in cube, would contain 17,000,000 pounds of potash, K_2O, which, if it could be extracted, would be worth, even at ante-bellum prices, $700,000. One ton of such an ore would contain 200 lbs. of potash, worth, if it could all be extracted, about $7. If we assume, however, that only 75 per cent of it would yield to a chemical engineering process, we still have $5 per ton in value to work for. When we remember that in large scale operations in the gold mining

industries, quartz that carries no more than $2 per ton in valuable constituents has been profitably worked, the problem need not necessarily frighten us away at the outset.

During the fiscal year ending June 30, 1914, there was imported into the United States fifteen million dollars' worth of potash salts, kainit, manure salts, muriate of potash, and sulphate of potash. In addition to this, considerable quantities of caustic and carbonate of potash, not included in the later available statistics, were also imported. Of the total, eight million dollars' worth was muriate of potash. The fertilizer industry uses, of course, the larger proportion of these potash importations, the percentage in the last few years being about 85 per cent of the total of muriate of potash imported, there being left about a million dollars' worth of muriate of potash which was used in industrial work. About half of this total, or half a million dollars' worth, was used to make caustic potash and carbonate of potash. These are used principally in the soap industries, although a portion is used as a wrapper tobacco fertilizer and in the manufacture of glass, paper, preparation of colors, in printing, in photography, and in more strictly chemical industries. Some nitrate of potash is manufactured from the chloride. About one-eighth of the muriate is manufactured into chlorate of potash at present, which is largely used in the growing safety-match industry. Potash bichromate uses about one-twentieth of the muriate and this is used in textile and color industries; also in photography.

Before proceeding with an analysis of cost data involved in the possible use of feldspar as a potash ore, it will be well to consider briefly the present sources of the world's supply. The German mines, located principally in the neighborhood of Stassfurt and Magdeburg in Prussian Saxony, have been for the past seventy years the principal source of the world production of the various potassium salts. Professor O. N. Witt, in an article in the *Chemiker Zeitung* of Oct. 8, 1914, states that borings in Alsace have shown favorable deposits which may prove to be of considerable value. This is interesting news in view of the present doubt as to the future political status of Alsace-Lorraine. The reported discovery of soluble potassium salts in the province of Catalana, Spain, has recently commanded considerable attention and was prominently mentioned in the last annual report of one of our large agricultural chemical companies. According to our latest consular

reports under date of Nov. 6th, 1914, potash has not been extracted in Spain up to the present time in commercial quantities.[1] If the Spanish prospects should develop so that they would become a basis of a world trade, they would be welcomed for breaking an existing monopoly, but the source of supply would still be over-sea, whereas North American independence in the commodity is highly desirable.

An American source of potassium salts in any considerable or practical quantity, in spite of much expensive government and private exploration, has not yet been discovered. In the Far West the giant kelps of the Pacific coast, some of the brines and bitterns of the saline lakes and wells, and the alunite deposits of Utah and Arizona have been proposed and studied as possible sources of potassium compounds. The fact remains, however, that up to the present time three-quarters of all the potassium salts used in agriculture are consumed east of the Allegheny Mountains, by far the greatest quantity going into the three States of North and South Carolina and Georgia.

The reasons for this segregated demand for potash fertilizers are not at once apparent. The authors have made inquiries and have received the following explanations. Cotton, tobacco, intensive orcharding and truck farming use the largest quantities of artificial fertilizer, while, in addition to this, the educational propaganda of a large Southern agricultural chemical company has demonstrated in its more immediate territory the economy of the proper additions of fertilizer to the land. The great effort which is now being made throughout the country to bring up the yield per acre of all our crops, will in all probability largely increase the use of all fertilizing materials not excepting potash.

It is unlikely that even the Panama Canal under the present tolls system would enable western potashes to meet European competition on the Eastern seaboard. The fact that the great feldspar dykes of the Appalachian system are in general located in close proximity to the places where potassium salts are in the greatest demand makes a special appeal to the chemical engineer. That the growing use for potassium compounds in intensive agriculture and industry will some day make use of the huge quantity locked up in the silicates, seems a safe prophecy. Whether that time has yet arrived is now open to debate.

[1] Consul General Carl Hurst's Report in Daily Consular and Trade Reports, Dept. of Commerce, 261, 615.

In this paper, the authors will confine themselves to a discussion of their own methods and chemical engineering experience. There is no intention to ignore the fact that other workers have also proposed or to some extent developed methods for extracting potash from feldspar, either with or without the simultaneous production of valuable by-products. With any or all such methods the authors are not in conflict or debate, the present object being merely to open the subject to discussion along a well-known line. If any other source or method of economically producing American potash is discovered, the authors will follow its development with much interest.

Our previous paper described the working of the process by which the insoluble potash in the feldspar rock was simply converted into the soluble chloride salt, but no separation of this soluble salt from the residual rock was made. The product contained about 4½ per cent water-soluble potash (K_2O) in the form of 7.1 per cent of muriate of potash (KCl), also about 16 per cent of free lime, and the balance was the insoluble mineral material. It was solely a potash-lime fertilizer.

Several hundred tons were produced in regular mill working, and 24 hour-a-day runs were made, so that the feasibility of producing this material continuously and regularly was fully demonstrated.

This fertilizer was distributed free of all charges to some score or more of State experiment stations and large growers in many States for field trials as a straight potash-lime fertilizer, to be compared with other potash fertilizers, such as wood ashes and various mixtures.

The field results were very favorable, as was to be expected from a material of this composition.

As will be shown later, the cost of production of such a potash fertilizer was low, but the added expense of freight charges on a material containing so much inert matter was a serious drawback.

Muriate of potash is the chief potash salt imported into this country. It is sold on the basis of "80% Muriate" and usually contains from 70 to 80 per cent KCl, or from 44 to 50 per cent K_2O. This material, having its values in such a small bulk, will bear the cost of freight shipment easily. It is the cheapest potash salt for use as a raw material for chemical manufacturing, and is also well adapted for mixing into general commercial fertilizers. Any potash salt, however, running not less than 17 per cent K_2O (or 26 per cent KCl) is adapted for use in mixed fertilizers. A salt

lower than 17 per cent K_2O could only be used where the final K_2O content in the complete fertilizer was to be less than 5 per cent.

Therefore, for the uses of the fertilizer industry, the economical production of any material containing 26 per cent, or higher, of KCl, would find large use, but for the replacement of all or a portion of the one million dollars' worth of concentrated muriate salts used yearly in the United States for chemical manufacturing, it is necessary to produce a salt containing at least about 70 per cent KCl.

Our experimental work was continued with the idea of separating and concentrating the soluble potash salts unlocked by this process, and giving a product so concentrated and pure that it may be used either in making fertilizers or be worked up into other potash compounds for more strictly chemical uses.

The salts are easily leached out from the mass as it comes from the furnaces, and by proper methods a solution of about 10 per cent KCl can be obtained, using the wash liquors for leaching new material. The evaporation of large amounts of water is a serious problem in chemical industry, and in this particular case it could not be accomplished cheaply by any of the usual methods of evaporation.

The engineers working on this problem, however, have had considerable experience with methods of evaporation by the direct use of hot waste stack gases. A Porion evaporator, using such gases, is an extremely cheap method of evaporation with furnace gases, provided the material in solution is not harmed by the gases themselves. Even cheaper than this is the method of spraying the liquor through the waste hot gases. Experience with this operation has developed such successful results that it was adopted for this particular work. This use of the hot kiln gases, otherwise wasted, has an added advantage in the potash process from the fact that any volatilized KCl is caught at the stack washer.

The chief technical difficulty in the conversion to KCl was due to the high temperature produced by the powdered coal flame. When the charge, moving down the kiln, is brought up to about 1050° C. the reaction is complete and there is then present in the charge free KCl. If the material is then further heated beyond 1150° C., some of the KCl is volatilized and passes as vapor toward the stack. This final overheating of the charge, and the volatilization of KCl, may be prevented by the use of a rotating combustion chamber attached to the lower end of the kiln, the charge passing

outside of the extremely hot zone which is inside the combustion chamber. This arrangement prevents all overheating and is so effective that coal itself is dried by this means, in a rotary dryer, with heat from burning powdered coal, the hot zone being confined to the combustion chamber rotating with the kiln. Small burners must be used in such cases, however, and in this potash work it is better to overheat than underheat the charge to obtain the full yield of soluble product. In the mill work described in our previous paper, when no rotating combustion chamber was used, about 16 per cent of the KCl was volatilized during its passage through the hot zone of the kiln. This is now all caught in the stack-washer.

The complete process for the final production from feldspar of potassium chloride salts similar to the concentrated muriates imported from Europe, will now be outlined.

A mixture of ground feldspar, containing about 10 per cent of K_2O and burned limestone, is formed into rounded aggregates or "clumps" about ¼ inch in diameter, by the device already employed, using a solution of calcium chloride for this purpose. Calcium chloride is the by-product of the ammonia-soda alkali process and is the reactive agent in unlocking the potash from the silica. Mixtures of powdered rock and dry calcium chloride are almost impossible to make, due to the attraction of the chloride for moisture. Moreover, simple mixing of two materials in the form of fine powders does not give an intimate enough contact of the reacting particles to produce good yields in furnacing operations in which neither of the particles is melted, so as to "wet" the other. In this particular case it was found that a proportion of burned lime mixed with the powdered feldspar will unite with $CaCl_2$ from a solution sprinkled on the powder, to form an oxychloride compound which cements the whole powder into aggregates, giving such a very intimate union of the particles that when heated the reaction yields are high. These aggregates or "clumps" pass directly into the rotary kiln heated either by oil or powdered coal flame. The clumps fall out of the kiln in the same form in which they entered it, but the potash has been converted from the insoluble form into the water-soluble muriate. These red-hot clumps fall into water in leaching vats, where the potassium chloride goes into solution. Several of these leaching vats are used so that the solution of the salt, the leaching, washing, etc., is continually performed. The strong solutions are pumped to the evaporators. The weaker wash

liquors are used as leaching liquids for a new lot of processed clumps. The strong liquor containing roughly 10 per cent of KCl will be continuously sprayed down through the hot gases passing out of the kilns to the stacks. This operation is well known and has been studied particularly by our engineers.

The bulk of the water in these solutions is thus evaporated and only very concentrated solutions or sludges are allowed to pass out. These very strong hot liquors are finally dried out in a rotary dryer placed at the head of the lime-burning kiln, using its hot waste gases. The crusts formed are then ground for the market.

The concentrated solution, before complete drying, contains a small proportion of sodium chloride, corresponding in amount to the proportion of Na_2O in the original feldspar. On a spar running 10 per cent K_2O the Na_2O content has averaged from 1½ to 2 per cent. This would give from the liquors completely dried at once, without any fractional separation of the NaCl, a product having about the following composition: KCl 70 to 80 per cent, NaCl 14 to 16 per cent, and the balance a very small amount of lime salts and moisture.

To compare this initial product with imported German muriates, we give the following analyses upon which such salts are usually bought in this country:

	70–75% Muriate.	80–85% Muriate.
KCl	72.5	83.5
K_2SO_4	1.7	
$MgSO_4$	0.8	0.4
$MgCl_2$	0.6	0.3
NaCl	21.2	14.5
$CaSO_4$	0.2	
Insol.	0.5	0.2
Water	2.5	1.1
	100.0%	100.0%

It is thus seen that without any attempt at fractional separation, muriate of potash may be made from our American feldspars, equal in character to the usual imported muriates, and that they are as well adapted to be used in commercial mixed fertilizers as those imported.

If the hot concentrated liquors are not at once brought to dryness

but are given a fractional crystallization treatment, which may be made a continuous operation, whereby most of the NaCl is removed, the KCl crystals then obtained will run pure enough to enable their direct use in the manufacture of chemicals of a high grade of purity. It may be noted that the purchasing analysis of German "90/95 per cent muriates" runs KCl 91.7 per cent and NaCl 7.1 per cent.

However interesting a workable process may be, it must, in order to be successful, produce the final product at a cost less than that of the same material obtained elsewhere. The costs of producing muriate of potash by this process will now be considered somewhat in detail, as we wish to present this subject for the careful consideration of engineers and manufacturing interests in this country.

The plant required is equipped in a general way similarly to a Portland cement mill. There must be rock hoists, trackage, crushers, rolls, rock dryers, grinding mills, a rotary lime burner, the "clumpers" and rotary kilns, coal dryer and grinder, besides bins, elevators and conveyors, also leaching vats, tanks for strong liquors and for wash water, pumps, flue arrangements at stack for spraying the liquors, dryers and pulverizer, also air compressor and general power plant, stairs, ladders, handrails, and buildings to house the plant.

Plant Costs and Annual Charges—In order to get the best idea of the various costs, we shall take a concrete example of a plant large enough to handle 300 tons of feldspar per day of 24 hours, this plant being a good-sized commercial undertaking. Such a plant will require three rotary kilns, each 100 feet long and from 7 feet to 8 feet diameter. We may conveniently divide the plant costs into two parts: (1) those for equipment usually present in Portland cement mills, and (2) those for special equipment and rearrangements necessary to carry out these potash processes.

(1) The equipment usually found in a cement mill of this size, which would be used in the potash work, is:

Quarry hoists, trackage, cars and tools	$4,000.00
Crushers, rolls, grinding mills	17,140.00
Rock dryers	4,600.00
(3) kilns 7 feet diam. × 100 feet (to 125 feet) long	24,000.00
Air compressor and piping	2,000.00
Power plant	20,000.00
Buildings, stairways, handrails, etc.	16,000.00
Miscellaneous equipment (14%)	12,260.00
Total	$100,000.00

(2) The special equipment and rearrangements required are itemized as follows:

Belt conveyors	$850.00
Screw conveyors	1,350.00
Elevators	4,300.00
Feeders	600.00
Chutes and gates	1,140.00
Bins for dry operations and $CaCl_2$	7,000.00
Lime kiln and burner	5,000.00
Oil or coal bins and incidentals	1,000.00
Clumpers (3)	5,000.00
Leaching, wash tanks and supports	18,400.00
Stack alterations and spraying apparatus	1,800.00
Liquor dryer and stack	2,800.00
Stack base	400.00
Disposal system (sludge)	1,000.00
Pumps and solution piping	3,500.00
Line shafting, pulleys and foundations	700.00
Miscellaneous foundations	250.00
Miscellaneous walkways, etc	600.00
Contingencies	7,810.00
	63,500.00
Superintendence, etc	6,500.00
Total	$70,000.00

Now, if 5 per cent interest and 7 per cent depreciation is figured on the first item of $100,000, the yearly fixed charge is $12,000. It may be possible to lease a cement mill with this equipment for this amount per year, and, if production was desired rather quickly, such a procedure would recommend itself. If the annual charge on this investment is then taken as $12,000, and there is added to it 5 per cent interest and 10 per cent depreciation on the cost of the special equipment, $10,500, we have as the annual charges to plant investment $22,500, or $64.30 per day.

Raw Material and Costs—We think there is a quite general misunderstanding as to the cost of the feldspar for this use. The only considerable use at present for feldspar is for the production of white china and porcelain ware, and for this purpose it must be free from iron-bearing minerals, such as biotite, garnet, hornblende, tourmaline, etc., in order that it will burn white. Therefore, all the feldspar that is put upon the market must be hand picked and iron free, and for such material the prices run from $3 to $5 a ton. For the purpose of producing potash salts from feldspar, it is not at all necessary that the raw feldspar be free from iron. In fact, this process should rightly be called a process for producing

potash salts from "feldspathic rock" instead of from "feldspar." Feldspathic rock underlies a large portion of the Appalachian system. Feldspar, free from iron, is a special mineral, occurring in dykes of high purity.

For the purpose of this business, what are now called "feldspar properties" would not necessarily come into consideration at all. The procedure would be to buy by the acre certain lands well located for the purpose and get the feldspathic rock out by open quarrying operations, the costs of which are low and are quite well known. Limestone is quarried rough for about 20 cents per ton, and cement rock is quarried in the Lehigh district for about the same cost. We have figured the cost at 50 cents per ton, and have allowed an equal amount for freight, making the cost of crude feldspar at the mill $1 per ton. This low freight charge is made, as it would be good policy to have the mill near the feldspar property and we regard this cost per ton as obtainable. However, we later on give the change in the final cost of the product with change in cost of the raw feldspar. Three hundred tons of feldspar per day at $1 would be $300 per day, or $105,000 per year.

The potash is unlocked from its combination as double silicate by the reaction with calcium chloride under heat, the potash and any soda present uniting with the chlorine, forming alkali chlorides. One part of K_2O requires theoretically 1.18 parts of $CaCl_2$, and one part of Na_2O requires 1.79 parts of $CaCl_2$. A feldspar rock containing 10 per cent K_2O and 2 per cent Na_2O will require 15.4 parts of $CaCl_2$. A charge of 300 tons of such feldspar will therefore theoretically require 46.2 tons of actual $CaCl_2$, and in practice some excess of the reactive agent is used. The technical difficulties encountered in making and handling mixtures of feldspar and dry calcium chloride and the means by which these difficulties were overcome, were fully described in our earlier paper. By having a small proportion of free quicklime mixed in with the pulverized feldspar, and by an automatic device by which a strong solution of calcium chloride is continuously sprinkled on a moving layer of the powder, separate aggregates of "clumps" are formed due to the combination of the free lime with the calcium chloride, with the formation of an oxychloride compound which cements the masses together into an extremely intimate union. The chlorine seems to be in a much more reactive condition in this temporarily-formed oxychloride compound than the chlorine in straight calcium chloride,

although the higher reaction yields obtained may be due merely to the far more intimate contact of the particles composing the clumps. These clumps are run directly into the rotary kilns.

This automatic method of preparing materials for furnacing operations costs only a few cents per ton and in this and in other furnacing processes it is greatly increasing the reaction yields. It is one of those simple aids to chemical manufacturing procedure which is tending to make continuous operations replace the methods of treating separate batches, and while often increasing the yields, it always decreases the cost.

We shall therefore figure the costs, using for every one hundred parts of feldspar twenty parts each of lime and calcium chloride, or for the plant we are considering, sixty tons of each per day. Provision has been made for a rotary limestone-burning kiln. Limestone can be quarried, brought to the mill and crushed to rather small size for under $1 per ton. At this figure the raw material cost per ton of lime will be $1.70. The cost for burning will be 63 cents per ton, the items of this cost being shown below in the figures for furnacing the feldspar mix. This gives $2.33 as the cost in the mill for a ton of unground lime and the daily charge will be $140 or $49,000 per year. It may be mentioned here that unusual care in burning the limestone is not required, although good burning is advisable.

Calcium chloride is the by-product of the ammonia-soda alkali process and is produced in great quantities in this country. A large portion of the amount produced finds no ready sale. It may be obtained in solid form containing about 75 per cent $CaCl_2$ and the balance water, or in solution in various strengths. The solutions used in our work are quite strong, between 35 and 40 per cent $CaCl_2$, so that the original solutions shipped in tank cars are suitable for the purpose. The questions of freight charges on the water content of solutions and solid cakes as affecting the final cost at the mill of the actual calcium chloride, has been gone into quite fully, and we feel justified in stating that in our opinion the net cost per ton of calcium chloride at the mill should not exceed $7.33. The sixty tons required per day will then cost $440, and per year $154,000. However, we later on give the change in the final cost of our product with change in cost of the calcium chloride.

Manufacturing Operations and Costs—Feldspar crushes and grinds more easily than limestone or cement clinker; it breaks easier

due to its cleavage planes. It has been found that a high speed mill which will grind 5 tons per hour of crushed limestone, so that 65 per cent will pass a 100-mesh screen, will grind 8 tons of crushed feldspar to the same degree of fineness. The operations of crushing, preliminary grinding and fine grinding of the feldspar and the lime so that over 95 per cent of the mixture will pass a 100-mesh screen, will cost about 16 cents per ton for power, 14 cents per ton for labor, and 10 cents per ton miscellaneous expenses, making 40 cents per ton total. The labor charge is for three shifts of six men each. This gives the cost for crushing and grinding the feldspar as $120 per day or $42,000 per year. Using the same figure per ton, the crushing of the limestone and grinding of the burned lime is $24 per day or $8400 per year.

The power required for the clumping operation is very small for a pump, elevator, feed roll and conveyor. Three shifts of four men each can handle it. The costs are per ton clumped, power 1c., labor 8½c., miscellaneous 3½c., total 13c., making a daily charge of $46.80 or per year $16,380.

The furnacing charges for heating the feldspar clumps are considerably less than those for burning Portland cement, as less heat is required, the maximum temperatures in the kiln being about 1100° C. or 2000° F. In our work with cement kilns it was found necessary to reduce the size of the coal burners, and cut the amount of coal fed in by at least one-third, or overheating would result. The coal requirements in burning limestone in rotary kilns show about the same reduction from Portland cement requirements, although a ton of quicklime requires the heat from about 75 lbs. of good coal for the actual decomposition of the limestone from which it is made. We do not know the amount of heat evolved or absorbed in the union of K_2O with the silica and alumina in the formation of feldspar, nor do we know the amount of heat evolved or absorbed when CaO unites with the same substances. The following data, however, are available:

$(K_2 + Cl_2) - (K_2 + O)$	evolves	114,120	gram calories
$(Ca + Cl_2) - (Ca + O)$	"	38,990	" "

Using these figures above, in a double decomposition where, on the one hand, calcium is removed from $CaCl_2$ and unites as CaO with silicates, and on the other hand, potassium leaves its union as K_2O with silicates and unites with chlorine to form KCl, there is evolved an amount of heat equal to 1440 B.T.U. per pound of K_2O. This

means that an amount of heat is evolved in the kiln at the reacting temperature, corresponding to 15.5 lbs. of coal for every ton of the charge heated in this process and by that much decreases the amount of fuel necessary to be burned. Our figures are 300 lbs. of coal per ton of burned clumps, but to this we add 20 per cent for the evaporation of the 17 or 18 per cent of water the original clumps contain. This gives a coal consumption of 360 lbs. per ton, or a cost of 45 cents per ton for fuel. Drying and grinding the coal costs 7 cents per ton of furnace product, power for the kilns 5c., a labor charge of three shifts of three burnermen each comes to 7½c. per ton, and adding 5½c. for miscellaneous expense gives 70c. per ton furnacing charges on the 420 tons per day produced by this plant. The daily charge is $294 and for the year $102,900.

The leaching of the furnace product has been done in a small way, but it has not actually been carried out at present upon a large scale, as no plant has had the necessary equipment. A complete equipment has been designed for a mill of the capacity we are considering. Four leaching tanks per kiln, each with a capacity of 2800 cubic feet; one tank for strong liquor for each kiln, with a capacity of 5600 cubic feet; and one common wash-water tank with a capacity of 19,600 cubic feet are provided, with all foundations, piping, pumps, walkways, etc. Also a rearrangement of the usual stacks so that the liquors are sprayed down through the hot kiln gases and in the same direction in which these gases are traveling at the time, dampers, direct by-passes, and a system for disposing of the residual mineral sludges to the dump. The power cost per day figures to $10.80; the labor of three shifts of five men each to $39, and adding $10 for miscellaneous expenses, the charge to this operation per day would be $59.80 or $20,930 per year. A 10 per cent solution of KCl pumped to the stack evaporators, if concentrated to a 30 per cent solution, will require the evaporation of 10.54 tons of water per hour in the three stacks. If the coal runs 13,000 B.T.U. this means the total heat from 0.91 ton of coal per hour. There will be burned in the kilns 3.15 tons of coal per hour, and it will require only 29 per cent of the heat generated in the kilns to effect this evaporation. This strong hot solution, pumped direct to the final dryer between the lime kiln and its stack, will require the evaporation of 3.7 tons of water per hour, requiring the total heat from 0.317 ton of coal. There will be burned in the lime kiln 0.44 ton of coal an hour, or an excess of 40 per cent. Should this not

be sufficient to effect the complete drying of the crusts of muriate of potash, and if it was necessary to add 50 per cent to the amount of coal burned, the added cost would be $9.50 per day, which would increase the total charges per day only 0.64 per cent.

The totals of the above costs are therefore

	Per Day.	Per Year.
Overhead expenses on plant	$ 64.30	$ 22,500
Raw materials	880.00	308,000
Manufacturing operations	544.60	190,610
Total	$1488.90	$521,110

PRODUCT—In our operation of this process in a Portland cement plant, 83.2 per cent of the insoluble K_2O in the feldspar was converted into KCl. This was done in a short kiln only 55 feet long, and better results are possible in longer and more efficient kilns. There is little doubt that 80 per cent can be obtained in the plant under discussion. From a rock containing 10 per cent K_2O there would be recovered, therefore, in the final product, 24 tons of actual K_2O in the form of 38.03 tons of KCl. This product should be about 80 per cent strength, therefore the actual final product will be 47.54 tons per day, or 16,639 tons per year, running 80 per cent KCl and a trifle over 50 per cent K_2O, a material identical with "80 per cent Muriate" imported from Europe.

The cost of this product figures to $31.32 per ton. The following table gives the costs in cents per pound and in terms of fertilizer units:

Product:	Per Day.	Per Year.
(80%KCl = 50.48%K_2O)	47.54 tons	16,639 tons
Actual KCl	38.03 tons	13,310 tons
Actual K_2O	24.0 tons	8,410 tons
Cost per ton of product	$31.32	
Cost per pound of KCl		
overhead	0.0845 cent	
raw materials	1.1570 cents	
manufacturing	0.7161 cent	
total	1.9576 cents	
Cost per pound of K_2O		
overhead	0.1340 cent	
raw materials	1.8333 cents	
manufacturing	1.1346 cents	
total	3.1019 cents	
Cost per "unit" of K_2O	62.04 cents	

Each change of 50 cents per ton in the cost of the raw feldspar rock changes the final cost of the K_2O in the product 0.3125 cent. Each change in cost of $1 per ton in the cost of calcium chloride changes the final cost of the K_2O in the product 0.125 cent.

If 80 per cent muriate of potash has been heretofore used at a cost in this country of $37.50 per ton, there is thus shown a saving by the above process of over $6 per ton, or 20 per cent profit on the manufacturing cost. All the materials for the operation are to be had in this country, and the costs as established by the first plant would not be increased in the future by any foreign complications. As to whether the German syndicate will continue after the close of the present war, we can only say that it seems probable, as under no conditions now foreseen will the Stassfurt potash deposits be separated from Prussia nor will Prussia be separated from her potash deposits. A very large proportion of muriate of potash from American feldspar rock would probably invite price cutting after the war. A reasonably small production, such as outlined in this paper, might supply the requirements of certain industries and still not be a large enough proportion of the whole amount used in this country to warrant a price war. Wise governmental measures might enable even a very large domestic industry to be built up, which would make us independent of foreign materials for this valuable and essential ingredient of our fertilizers. If the crop yields per acre are to be increased in this country, some such independence may be necessary. The permanent assurance that the fertilizers of this country may be supplied from domestic sources and that miscellaneous industries, such as the soap, glass, match, color, photographic and strictly chemical industries using $1,000,000 worth of potash a year can be assured of a constant source of supply would go far to stabilize a great many of our manufactories and would, by so much, be an item of true progress, as the raw materials are not at the present time used for any useful purpose whatever. It may be of some interest to record in passing that the present war conditions abroad have caused the market price of muriate of potash to rise. Last week we were quoted this material at about $100 per ton. If a plant of the size we have been describing was put into operation by leasing a cement mill and expending $70,000 on additional equipment, which could be finished in three months' time, and if

the muriate of potash was sold at one-half the present quoted prices, or $50 per ton, the profits figure out as $26,300 per month. After three months' operation the plant would have been paid for and at any time afterwards the plant could be scrapped and a good profit still be made on the enterprise.

We have made no attempt to put a value upon the large amount of by-product rock matter. In the plant we have considered, there would be produced, figured on the dry basis, about 370 tons of this residue per day. It would have a composition about as follows:

Silica (SiO_2)	65.8%	
Alumina (Al_2O_3)	17.4%	
Lime (CaO)	13.5%	
Magnesia (MgO)	1.0%	
Potash (K_2O)	1.9%	(?)
Soda (Na_2O)	0.4%	
	100.0%	

Owing to the volatilization of ferric chloride, the material is almost pure white and might find use in the glass, pottery, porcelain or brick industries. It is similar in chemical composition to some clays, except that it has a higher content of lime and a considerable proportion of this lime is already combined with the silica. Some use in glazes might be found. Although high in alumina, certain glass products might be made, using it in mixtures, particularly plate glass and some bottle glasses. Its freedom from color is a point in its favor and also the assurance of practically constant composition and physical condition. If 50 cents a ton could be obtained for it after being dried, the income would be about $120 per day. This would reduce the net cost of the 80 per cent muriate product to $28.80 per ton, and the cost of the K_2O to 2.85 cents per pound.

Conclusion—In concluding this paper, the authors wish to record the fact that they are already familiar with many strong arguments which can be used against the advisability of attempting to manufacture potash in the United States. It is frequently stated that the Stassfurt potashes could be sold in this country for about one-third of the prices which prevailed before the war and still yield profits to the foreign mines. Whether this statement is accurate or not, we have no means of ascertaining, but even if it is nearly true, it clearly proves that the words used in the introduction to this paper

were not too emphatic, in which it is pointed out that special interest rather than the cost of production has controlled prices. If potash has any bearing whatever, through intensive agriculture, upon the production and price of food crops, however indirect this bearing may be assumed to be, the control of the product by any single interest is unquestionably hurtful to the best interests of the people of this country. In the opinion of some more or less well informed persons, potash is not nearly so important to growing crops as the other principal plant foods, combined nitrogen and phosphates. In other words, there is a tendency in certain quarters to believe that the propaganda in favor of the widespread necessity for potash in fertilizers has been overdone and that our agriculturalists could rest contented with potash reserves in the soil for many years to come, provided other conditions are properly looked after. However this may be, it is difficult to persuade either the practical grower or the scientific agriculturist that he does not increase his yields and early bearing, by a wise use of potash in one form or another. Up to the present time, the statistics of our average crop yields per acre are not a source of pride to those of us who study such comparative data. It is the earnest belief of the writers that the American demand for an American source of potash at a fair price will continue to increase in the future. Whether the time has arrived when any progress along this line can be made, still remains in doubt. The foregoing paper has been offered to the Institute with no pretence at settling this important question, but merely as a contribution to which we invite the attention and consideration of chemical engineers and others who may be interested.

DISCUSSION.

Dr. H. A. Huston, Secretary German Kali Works, 42 Broadway, New York: I don't want to get into any argument, as the boy said when the teacher asked what the shape of the earth was. He said: "It is round." The teacher says: "How do you know it is round?" He says: "I don't know; it don't make any difference to me. You can make it square, if you like."

I did want to correct a statement in the paper—the fact that there was $15,000,000 worth of potash imported in 1914; because nobody knows how much is to be imported in 1914, but it will not be half that amount.

Dr. CUSHMAN: I didn't mean to say that—I was speaking of the fiscal year ending June 1st, 1914.

Dr. H. A. HUSTON: In regard to the American supply of available feldspar for making potash, a very interesting gentleman called at our offices the other day and offered us 15,000 tons of sulphate for 1915 and 40,000 tons for the year following, which he said he could make from feldspar at a cost of $18 a ton from 13% feldspar. He said he had a nice experimental plant, asked us to go and see it; I suggested he go and build a commercial plant. He said: "There isn't a pound of feldspar in the United States fit to make potash salts from;" that he has the only available supply.

That is not an unusual experience, at all. They come around and offer to us large quantities of different things, and at quite an advance on the price charged in the States.

I grew up in the feldspar quarries of New England, and I have never been able to bring myself to feel that there was much opportunity for making commercial potash out of it; and I don't see that these figures show it. The maximum price for 10% of water soluble potash at the German mines is only $2.11 a ton; and that is long ton, at that. That is less than the cost of the quarrying of feldspar. I inferred from the paper that the understanding was that minimum prices are fixed by the potash law. That is not the case. The maximum price was fixed. The mine can give it away, if it wants to, excepting it cannot go to mussing up the export business. (Laughter.) If the maximum price should be reduced to a dollar it can be exported for a dollar; but the only funny part of the law is that the maximum domestic price shall be the minimum export price, which is a fact of the general conservation policy of the German Empire.

The Alsatian mines referred to, have been in operation a long time; and we got 12,000 tons out of them in this country last year. In regard to the Spanish alleged discoveries, we knew all about that long before any war came up. Our agents were aware of the state of these prospects; there is some question as to whether anything of commercial importance will be found there.

I am very sorry about one thing: I hate to work when I don't have to; and this complaint that the potash propaganda is being overworked would seem to indicate that I have been overworking.

THE HARDWOOD DISTILLATION INDUSTRY IN AMERICA

By EDWARD H. FRENCH and JAMES R. WITHROW

Read at the Philadelphia Meeting, December 4, 1914

In view of the economic importance of the utilization of wood waste, and the increasing interest manifested in this utilization, it naturally surprises the inquirer that there is practically no literature upon this industry from the point of view of actual American practice. It may not be without value therefore to consider the progress made in hardwood distillation, and to trace its development from its inception in this country. We have gathered together consequently and classified much of the information which we have acquired in the plants of this industry during an experience in it totalling about 25 years.

This tracing of the development of an industry of the magnitude of this one is peculiarly interesting to the engineer, since it shows the necessarily slow evolution of the industry in the hands of the unscientific manipulator, and serves not only to emphasize the advantages possessed by the modern chemical engineer, but also to indicate how much more rapid the development might have been in the hands of experienced chemical engineers. It indicates also that in the future under the direction of the competent engineer important advances may be made much more rapidly than in the past. This latter statement is significant when it is remembered that progress thus far has been due either to accident or very often to workmen endeavoring to minimize the laboriousness of their work. As plants are operated on 12-hour shifts, this desire to economize energy may be readily understood.

For much of the historical information collected we desire to express our appreciation to Mr. Robert Mackay, who has been active in this industry for so many years. In fact during the past fifteen years our own continued intimate acquaintance with Mr. Mackay has been not only of unusual pleasure but of continuous instruction.

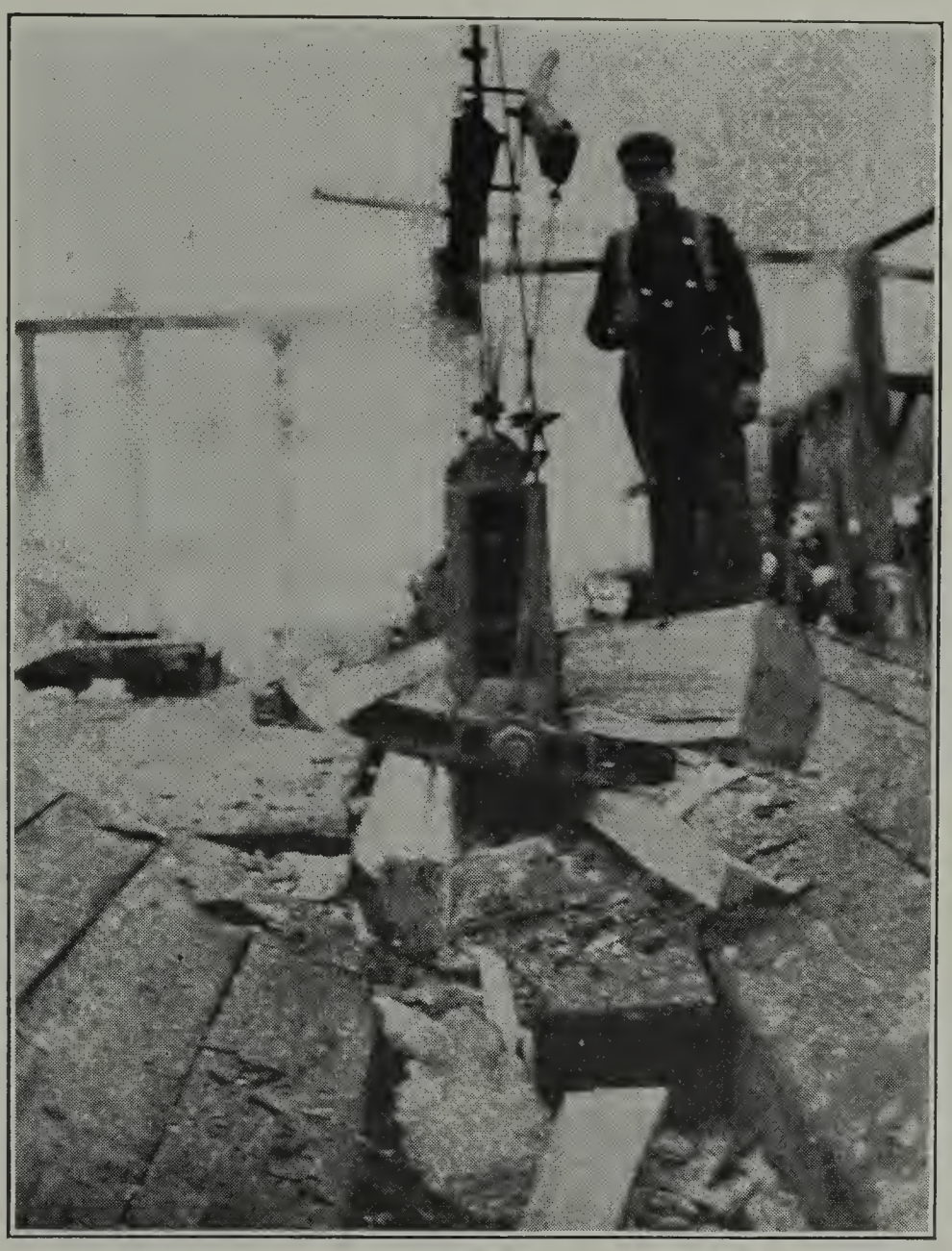
A history of this industry would be incomplete without mention of the fact that, due largely to his personality and integrity, the firm with which Mr. Mackay is identified, has had the unusual experience, in an extensive industry, of supplying engineering materials for every plant of this nature in the United States and Canada with perhaps two exceptions, for a period covering the past 25 years.

Sledges, Most Economical Means of Delivering Wood.

Early History

While charcoal burning was doubtless carried on in the earliest days in this country it was not until 1830 that James Ward began the manufacture of pyroligneous acid, at North Adams, Mass., according to Monroe and Chatard (12th Census, United States, Bull. 210, Chemicals and Allied Products, p. 34.) No claim is made that the pyroligneous acid was carried further though it may have been. We have ourselves no information on this matter other than the above citation. As far as we can ascertain it was not until 1852 that works in the modern sense were inaugurated for the distillation of wood for the production of volatile products, and their semi-refined products. This does not appear in agreement with W. L.

Rowland, (Special agent 10th U. S. Census on Chemical Products and Salt, p. 23) who is later cited by Monroe and Chatard (ibid.) and C. L. Campbell (Met. and Chem. Eng., 1910, p. 155), all of whom state that the manufacture of acetate of lime and methyl alcohol was started in the United States about 1867 by James A. Emmons and A. S. Saxon, in Crawford Co., Pa. Our information in this case



Canadian Cordwood Splitting Machine.

comes from various manufacturers who have been in this business from the earliest times or at least whose family connection with it goes back to the beginning. One of these sources is Mr. Neil Patterson, whose father was in charge of the original "Scotch Works," built in 1852. In this year The Turnbull Company of Glasgow, Scotland, who were engaged in the copper on iron industry as well as that of wood distillation, built the first operation in this country, by

way of expanding their old country business. The place chosen for this location was known as Millburn, New York, now Conklins Station, on the D. L. & W. R. R. not far from Binghamton. (Mr. J. L. Stuart of Corbett and Stuart, one of the earliest firms in this business in this country, informs us that the date 1852 given by Mr. Patterson for the building of the Turnbull plant should be 1849.)

The Turnbull Company brought with them their apparatus as well as men experienced with their methods. On account of these

Open Season Cordwood Delivery. Forest Fire Smoke in Background.

Scotch workmen the works became known as the "Scotch Works" and this name has clung to it to the present time, although the original workmen gradually went with new operations which started shortly after this one. They had much to do with the subsequent expansion of the industry, all of them being later in charge of new works.

It is interesting to note in connection with this first plant, that it was a type that was copied in detail in the construction of those that followed, for many years afterward. All these plants were equipped with cast-iron cylinders 42 inches in diameter and 9 feet

long, set in pairs, thus each pair held about 1¼ cords of wood. The wood was cut seven feet long and the charge "run off" every 12 hours, and six days a week. The stills and pans were operated during these early days exclusively by direct firing. The fuel used for the retorts, stills and pans was the charcoal produced, over which was poured the residual tar to make a quick fire.

This original works was followed in 1865 by Emmons and Co., of Brookdale, N. Y. In 1868 Alonzo Smith started a plant at

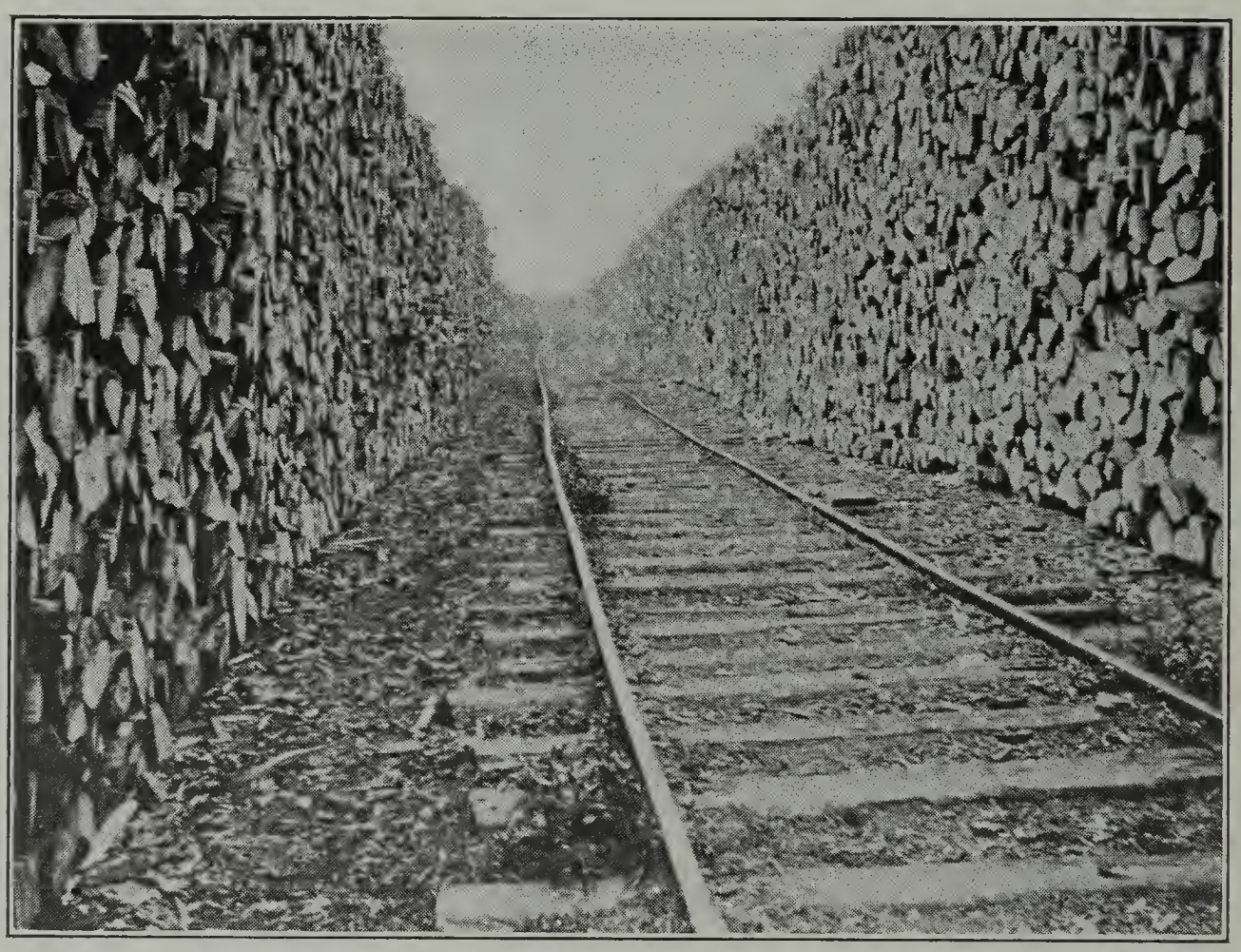
Typical Pennsylvania Wood Yard, Largely Beech.

Sturroco, Pa.; Keery Brothers, Cadosia; Mandaville, Emmons, Corbett and Mitchell, Livingston Manor, N. Y.; King and Co., Acidalia, N. Y.; Hilton and Co., Hiltonville, N. Y.; Brand and Schlayer; Frink and Ross; Tyler and Hall; Inderlied and Co.; Bayliss and Berkalue and Wright and Co., were also early in the field.

During the early part of this period of development, the chief product desired was acetate of lime, for which from 12 to 15 cents per pound was obtained. The alcohol demand was almost negligible, that which was made was of very inferior quality and was kept in

barrels, and most of it was lost by evaporation or through some "illegal vent." The charcoal also had but little commercial value and was largely consumed as fuel at the works, although a small local demand gradually developed starting with the neighboring tinsmith.

The change from the old charcoal heaps or pits to the kilns probably came quite early and perhaps before any of the improvements we have mentioned. It was not until 1876, after the retort system



Close View of Wood Yard.

was well established, and markets for its products had been developed, however, that Dr. H. M. Pierce's inventions made it possible to utilize partially the products wasted in the smoke from the charcoal kilns in Michigan, where great quantities of charcoal were prepared for blast-furnace use.

The earliest attempt at refining alcohol, so that it might be of commercial value was made by a Mr. Pollock, a chemist living just out of New York City. In a short time a demand began to develop for this product, which steadily increased, and up until 1880 was at all times up to the dollar mark. It was during this period that

that need of better refining was felt, as it was realized that a large loss was entailed in the refining operations. This necessity accounts for the coming of the Burcey Pans in the early seventies. These are copper containers placed in the vapor line above the stills, with deflectors inside to project the vapor against the upper shell of the container, upon which a stream of water runs, causing fractional separation of the water from the alcohol vapor. The increase of alcohol product resulting from this improvement, together with the

A Sixty-seven Cord Pennsylvania Plant.

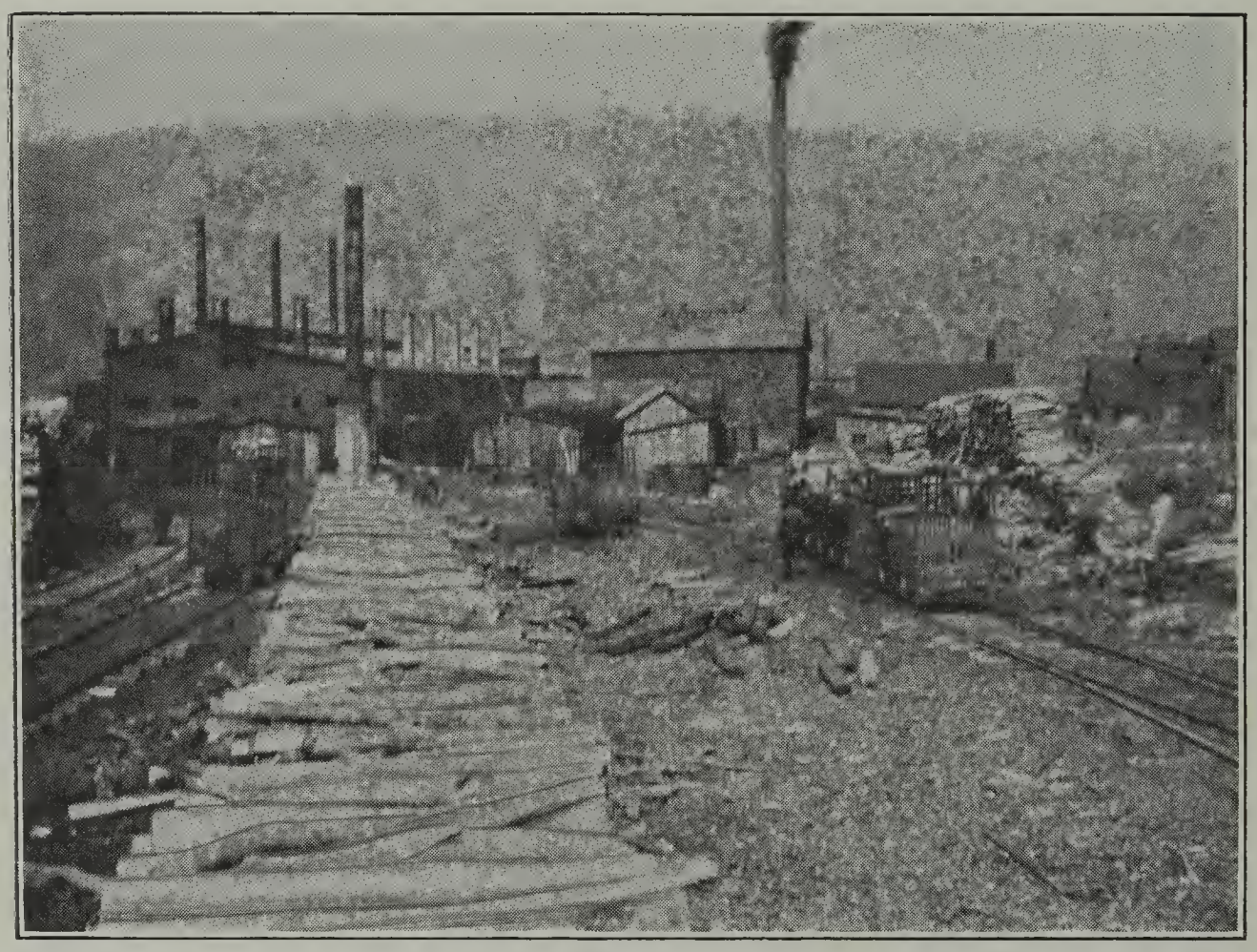
increasing market demand, made a central refinery necessary, and the producers united in building a refinery at Binghamton, N. Y., known as The Burcey Refining Company. This was in the middle seventies, and the plant is still in operation. It has served a good purpose, and to it was due perhaps more than to anything else the substitution of steam for direct fire distillation.

Before leaving this early history, it should be mentioned that the Turnbull plant, and in fact several succeeding plants, had but four pairs of retorts, or 5 cords capacity to the charge, thus by obtaining two charges within 24 hours their total wood consumption was

about 10 cords per day. To-day there are single plants operating 160 cords daily. Thus we have an illuminating comparison, at least so far as size is concerned, of the development of the industry.

Design of Apparatus.

Even at the present time, there remain many plants using the old original retort system, with one very slight modification.



Oven House of a Sixty-six Cord Plant.

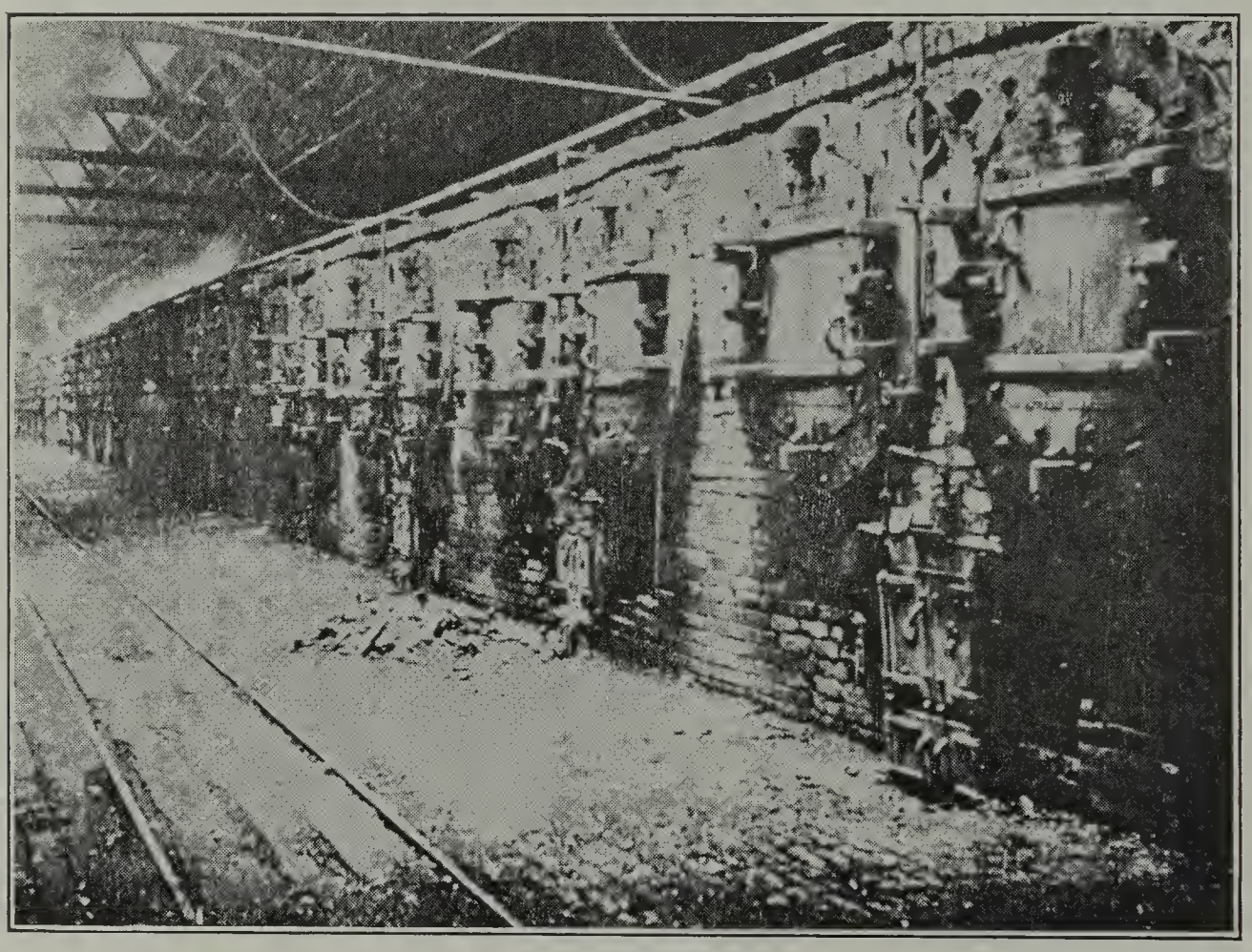
Those first in service were of cast iron, while the later ones have shells of steel with riveted cast-iron necks and fronts. The purpose of this change was due to the fact that in the early operations, since the wood was then of much less value than later, and high yields were not so important, it was charred at a very high temperature, in order to increase as much as possible the capacity of the plant by shortening the time of firing. As cast iron was much more durable for these high temperatures than steel, this use of cast iron retorts was universally practiced. When, however, with the coincident rise in the cost of wood, it was found that lower tempera-

tures gave an increase of all products, it was seen that steel could be employed to advantage, for its lower weight permitted the turning of the retort. This turning refers to the saving in apparatus universally practiced, and consists merely in the removal of the brick setting when the side in contact with the fire becomes buckled, rolling over the retort and placing the uninjured part next the fire, thus

A Twenty-eight Cord Plant, from Charcoal Dump.

materially increasing the life of the retort. This modern retort is of uniform size and design in all plants which still use this type of apparatus. The shell, as originally, is 42 inches in diameter and 9 feet long, supported at the ends in a cast-iron cradle and having a cast-iron front, with door and lugs, for pinning the door shut. At the rear is a neck 10 inches in diameter, to which is attached the condenser.

The evolution of the condenser is especially interesting in view of the fact that when the original condenser was installed each succeeding plant accepted it as being of proper size, and the new installation was made the same size. Then from time to time some one would discover that an addition would yield more product and at once the arbitrary sized unit was changed. Originally the worm condenser was used, but it soon became apparent that the heavy carbon bodies caused clogging, and soon the log condenser was substituted and was used until the introduction of the upright tubular one.

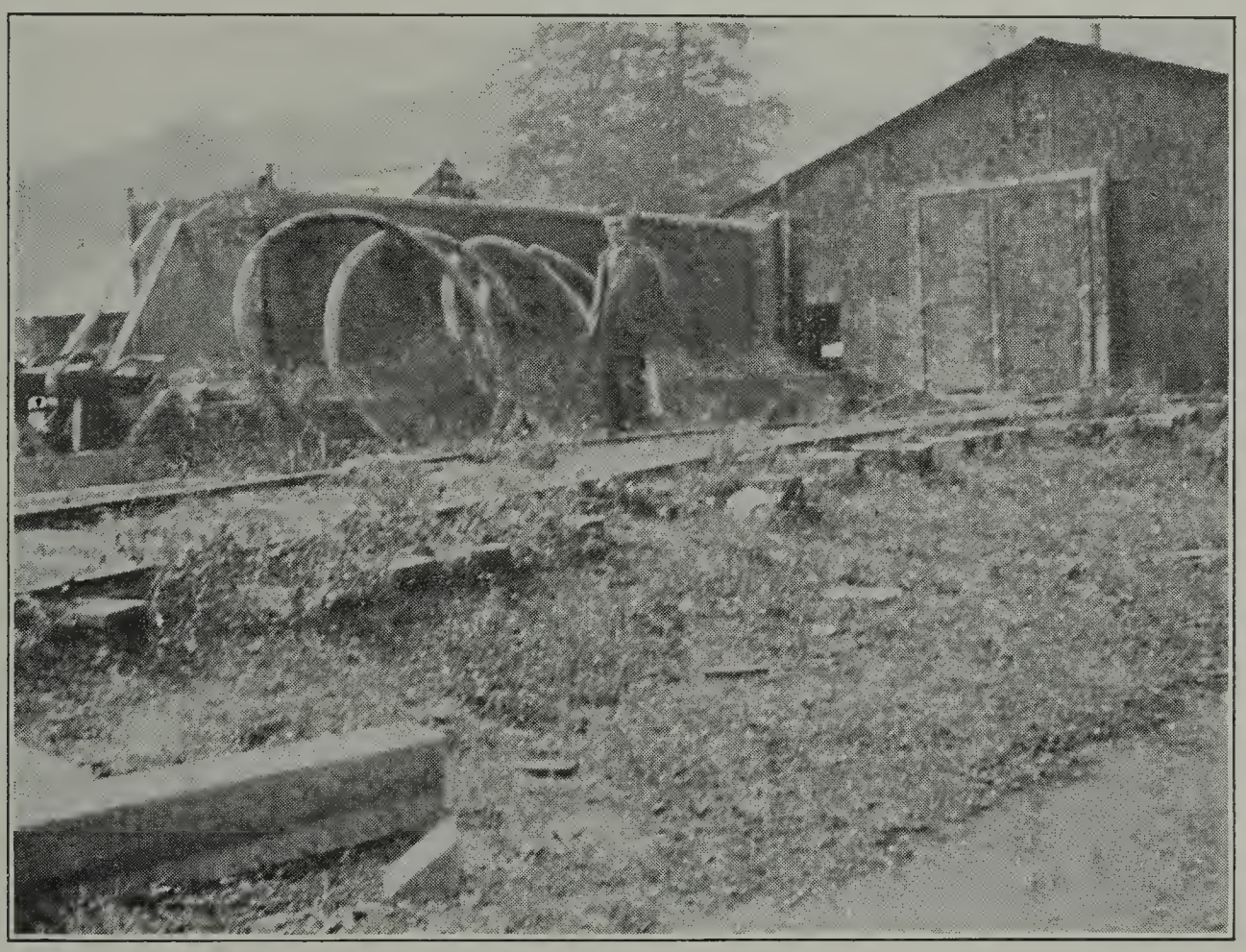


Retorts of a Forty Cord Retort Plant, still in Operation.

These log condensers were made by attaching by a copper tee, a large sized copper pipe, called the "log," to each of a pair of retorts. Near the ends of this pipe were copper connections, joining the large log to a smaller one, and this in turn was similarly connected with others progressively decreasing in size. The whole log condenser lay in a plane at an angle of 45° and the whole was surrounded by a wooden box with water inlet at bottom and outlet at the top. The joints were simply slip joints and were slipped together and "sweeled;" that is, wrapped with a cloth liberally covered with red lead, which after becoming dry or "set" offered a suitable and ef-

fective joint. At the ends of the logs were removable slip joint caps, for cleaning purposes, thus the cleaning from the heavy tarry and carbonaceous bodies was easily accomplished.

The first really important change in the general style of operation was that of replacing the old retort by the oven, which was done in the middle nineties, and is claimed to have been first tried out at Straight Creek, Pa. This change was wholly mechanical, and consisted merely of substituting for the retort a large rectangular oven,

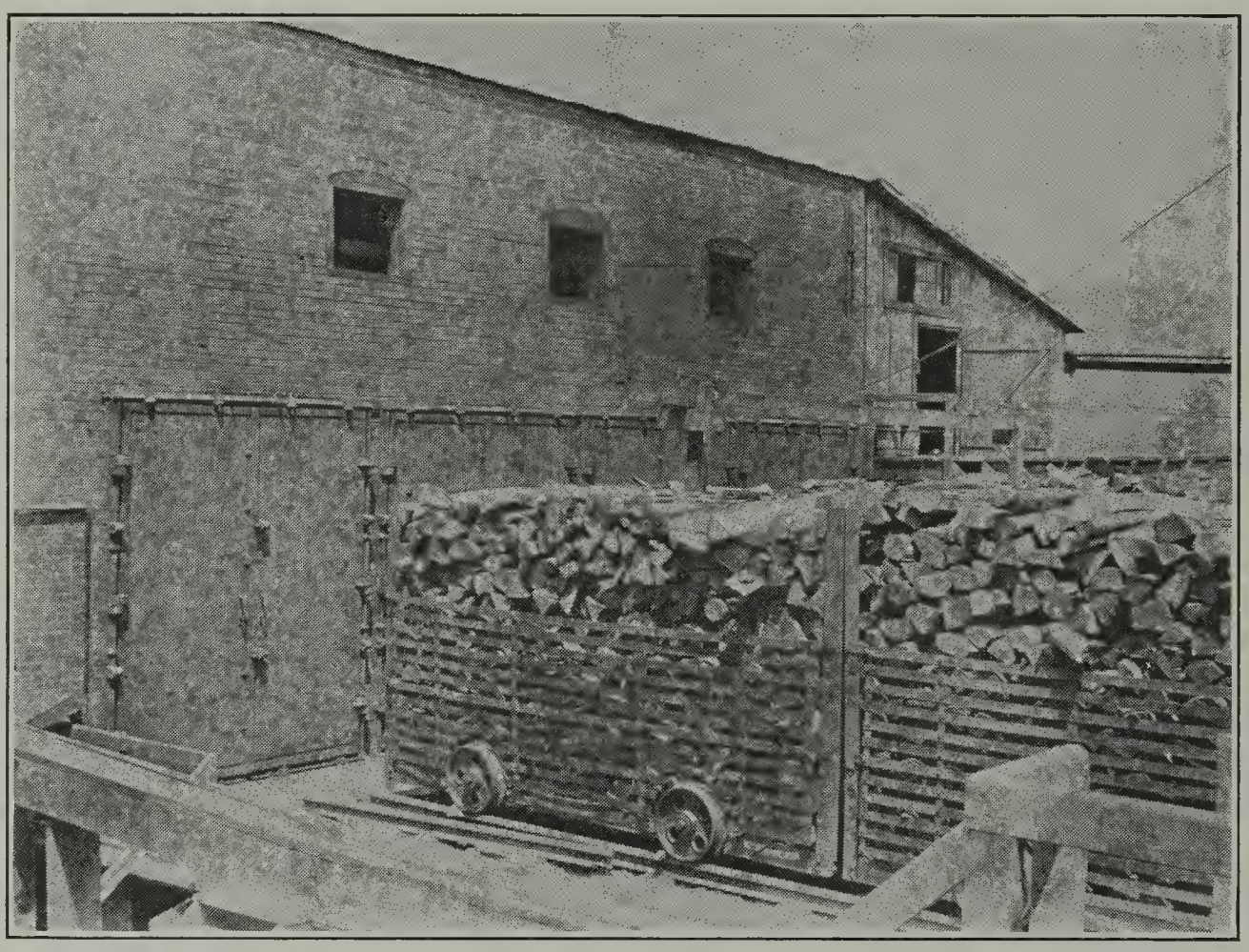


Hand Windlass, Cooler, Storm Doors of Original Experimental Oven, and Modern Copper Still Coils (Pennsylvania).

equipped with rails on the bottom for the purpose of carrying cars. These cars were loaded with wood and could be quickly pulled in and out mechanically and the charcoal unloaded outside the oven, greatly increasing the economy in this part of the operation, over the slow hand drawing of the charcoal of the retort system.

There appears to be, however, many more advantages in this style of operation than the mechanical advantages which were at first anticipated, as an increased yield of products is obtained, due undoubtedly in part to more advantageous manipulation, but in our opinion also to the different chemical reactions that take place. In

the old retort system complete carbonization of the wood took place in about 16 hours, and it required in the oven system 24 hours, yet the temperature of the gases at the neck are higher in the latter, running at a maximum under skillful manipulation to about 330 to 360° Centigrade, while in the former case the operation was consummated at not over 290° maximum. This maximum temperature is obtained about midway, or two-thirds of the run, at which time a very decided exothermic reaction takes place, and care must be exercised

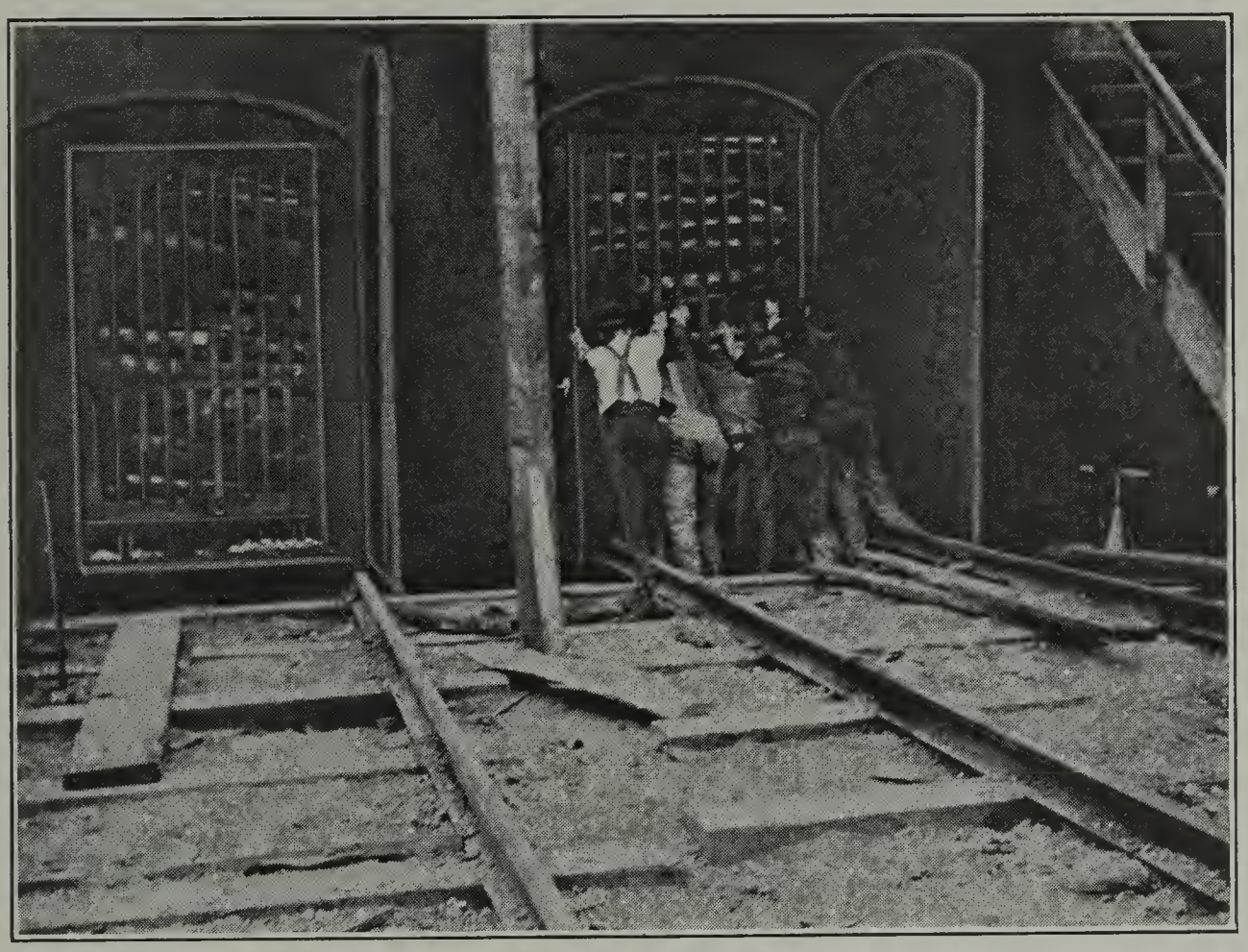


Loaded Wood Cars at Oven.

that the liquor is not "burned," that is, that the temperature is not permitted to rise, so as to avoid undue formation of condensation products, which would be immediately seen in an increased flow of gas and a darkening of the crude liquor. This exothermic reaction, which also takes place in coal distillation, probably accounts for the increase in temperature of the uncondensed gases in the oven system, since no greater proportionate radiation takes place in this system than in that of the retort construction. At this particular stage, on account of the nature of the source of the heat (exothermic changes in the wood), a much more uniform

temperature throughout the oven is maintained. This gives an excellent illustration of the possibility of considerable alteration even in the chemistry involved in a process, when we change the mechanical manipulation.

An additional advantage obtained by this oven system is that the charge of residual charcoal may be drawn while the oven is still hot, thus economizing on the fuel necessary for reheating, while a partial cooling is necessary in the hand-drawn retort system.

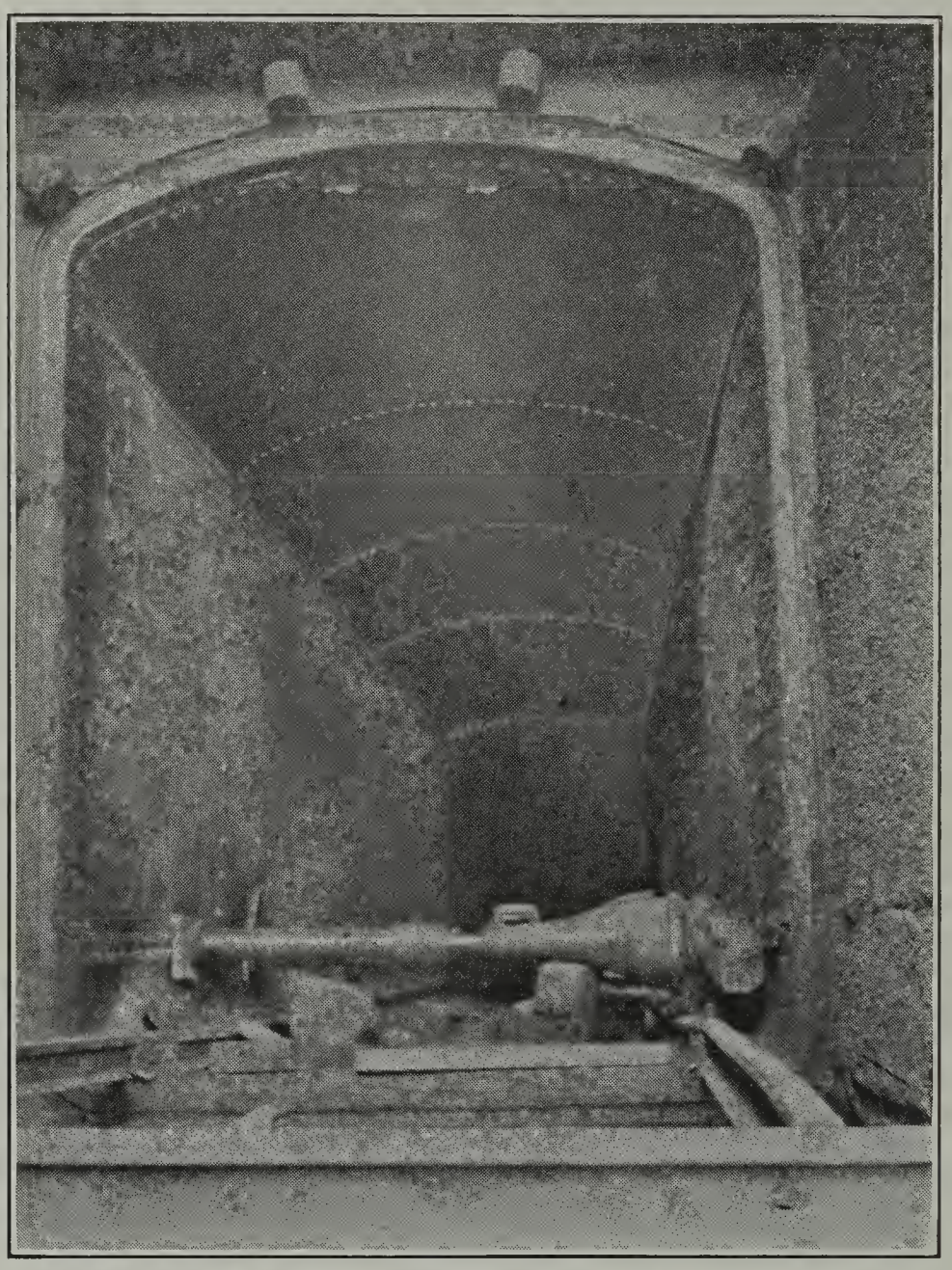


Setting Cars in Oven.

The time lost during this cooling was saved in one design near Dahoga, Penna., where the retort at the conclusion of firing was removed by a crane from its vertical setting and replaced at once by a previously charged retort. It is stated in the meager literature on this industry that "this type is probably most used."[1] This Dahoga installation, though it operated for many years, was the only plant that ever was installed in this country as far as we are aware and certainly there is little likelihood of any existing now for this one was recently converted into an oven plant.

[1] Met. and Chem. Eng., 1910, p. 155.

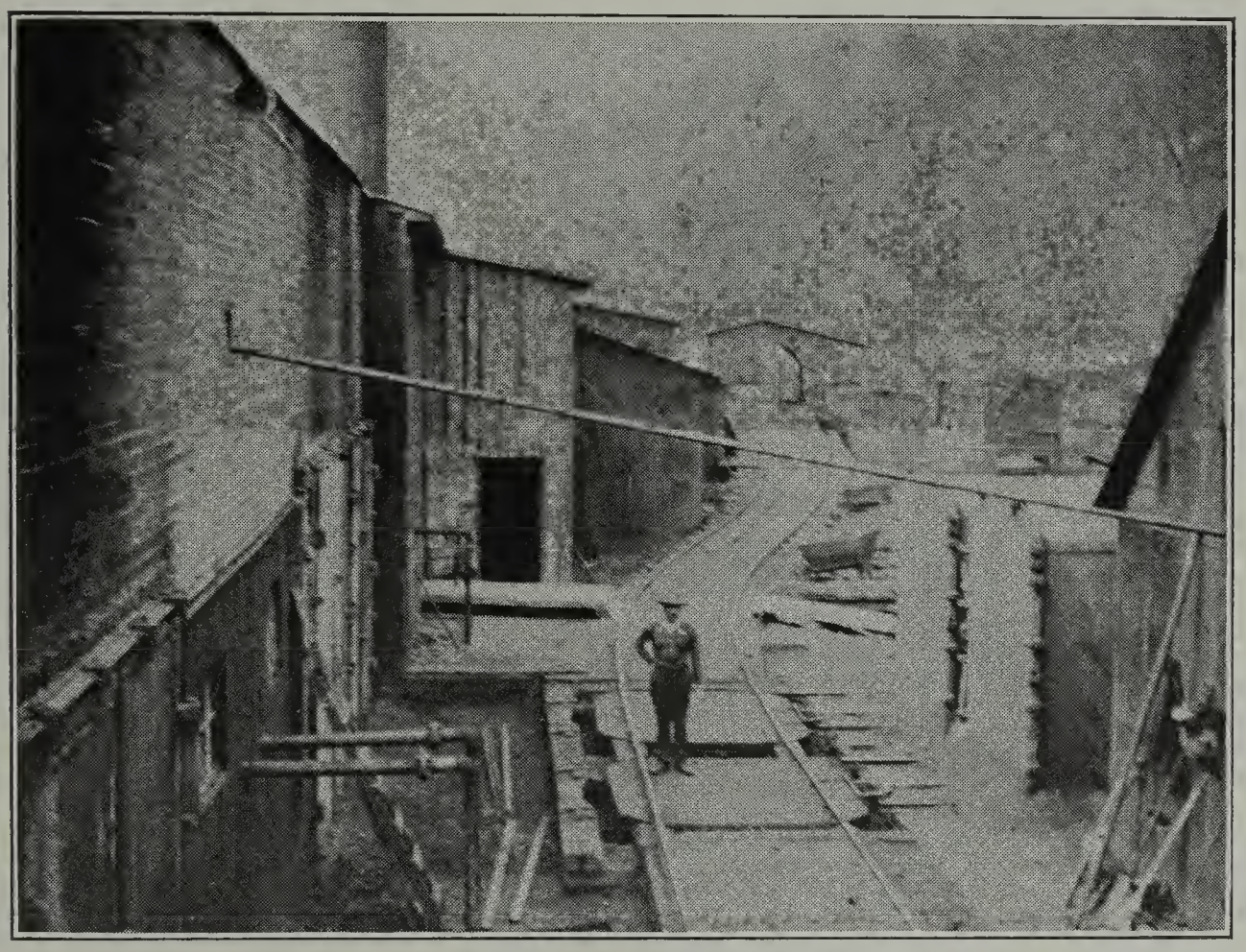
There is still a third system, which should be at least mentioned, namely the kiln system. This was really the second in date of development but the oven system was so closely allied in design and operation to the original retort system that the two were taken up together. The fact is, we would expect the logical development to have been: charcoal-heap→charcoal-pit→charcoal-



Spreading a Buckled Oven. Carbonaceous Incrustation on Door.

kiln→by-product-charcoal-kiln→retorts→ovens, but this does not appear to have been the case, in this country at least. As in the coke industry, we do not appear to have gone from Bee-hive-oven to By-product Bee-hive-oven, directly, but through the By-product-oven, an outside and distinct invention, so in this industry, the charcoal kilns were converted into the by-product kiln system only after the development of the retort system.

When charcoal was produced in kilns, from 20 to 86 cords of wood were placed in a kiln constructed of bricks, and wood was used as fuel for carbonizing. The volatile products were lost through the opening provided at the top. With the advent of markets for alcohol and acetate, some charcoal manufacturers placed a pipe connecting this opening with a suction fan and a condenser and thus collected the volatile products. The amount of product

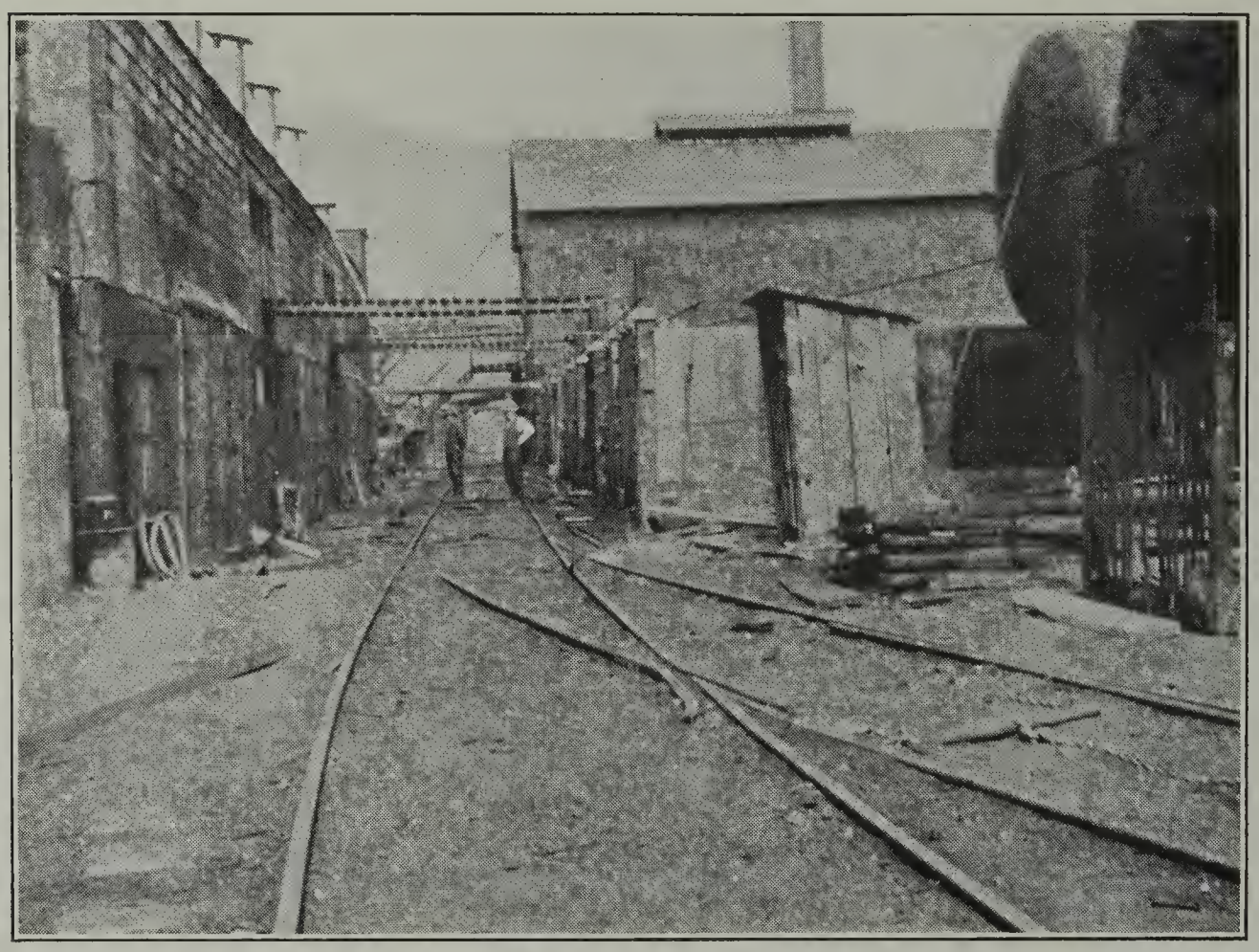


Turntable System Necessary for Single-ended Ovens. An Eighteen Cord Plant. Charcoal Tipple in Background.

thus recovered is but a fraction of that recovered in a retort or oven system. In Pierce's system the flat-topped circular kilns usually hold 50 cords. They are heated by gas burned in a furnace under the kiln. For the sake of brevity, a description of these interesting kiln plants will be omitted since their recovery of by-products is low and they are confined almost exclusively to the blast furnace plants of Michigan where they are steadily and rapidly being displaced by oven plants.

Yields.

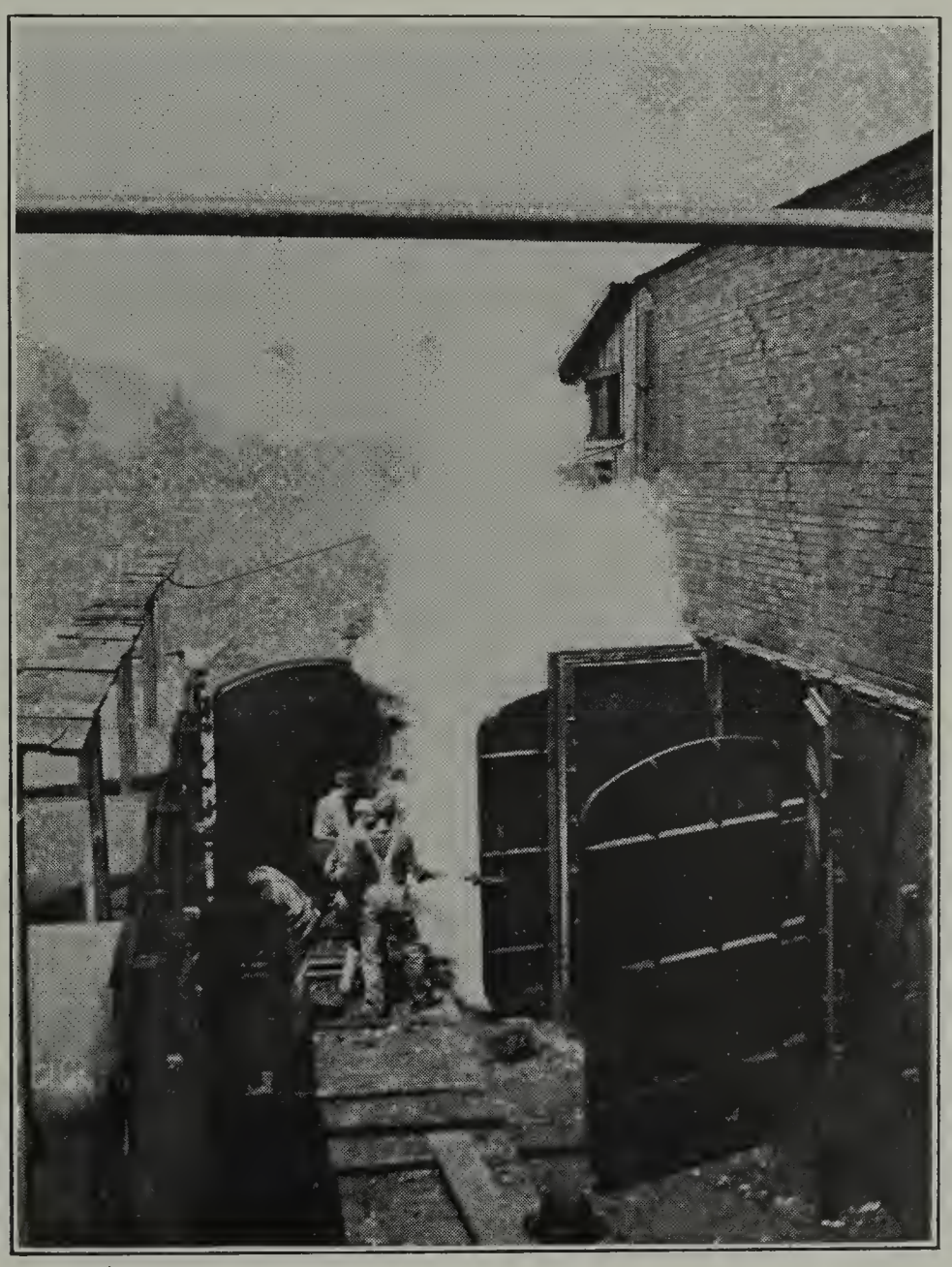
The low yield from the kiln system, which runs about 100 lbs. of acetate of lime and 4 gal. of alcohol per cord, together with the low yields obtained by *rapid or quick* firing plainly show that there is a mean temperature which gives the maximum yield. Just what the curve of efficiency is, to our knowledge has never been definitely determined in a commercial plant, though we have given



Ovens, Alcohol Storage and Still House in a Congested Plant. Aerial Liquor Runs in Background.

it much experimental attention and others doubtless have worked on it also. In fact, there are so many factors to be considered in a comparison of experimental operations on a commercial scale that while the factors causing increased or lessened results are known, it is difficult to obtain accurate definite knowledge as to just how much each factor contributes to the results. For example, we know that Michigan plants under approximately the same construction and operation obtain less product per cord than those of New York and Pennsylvania, without certain knowledge of the relative influence of the various contributing factors.

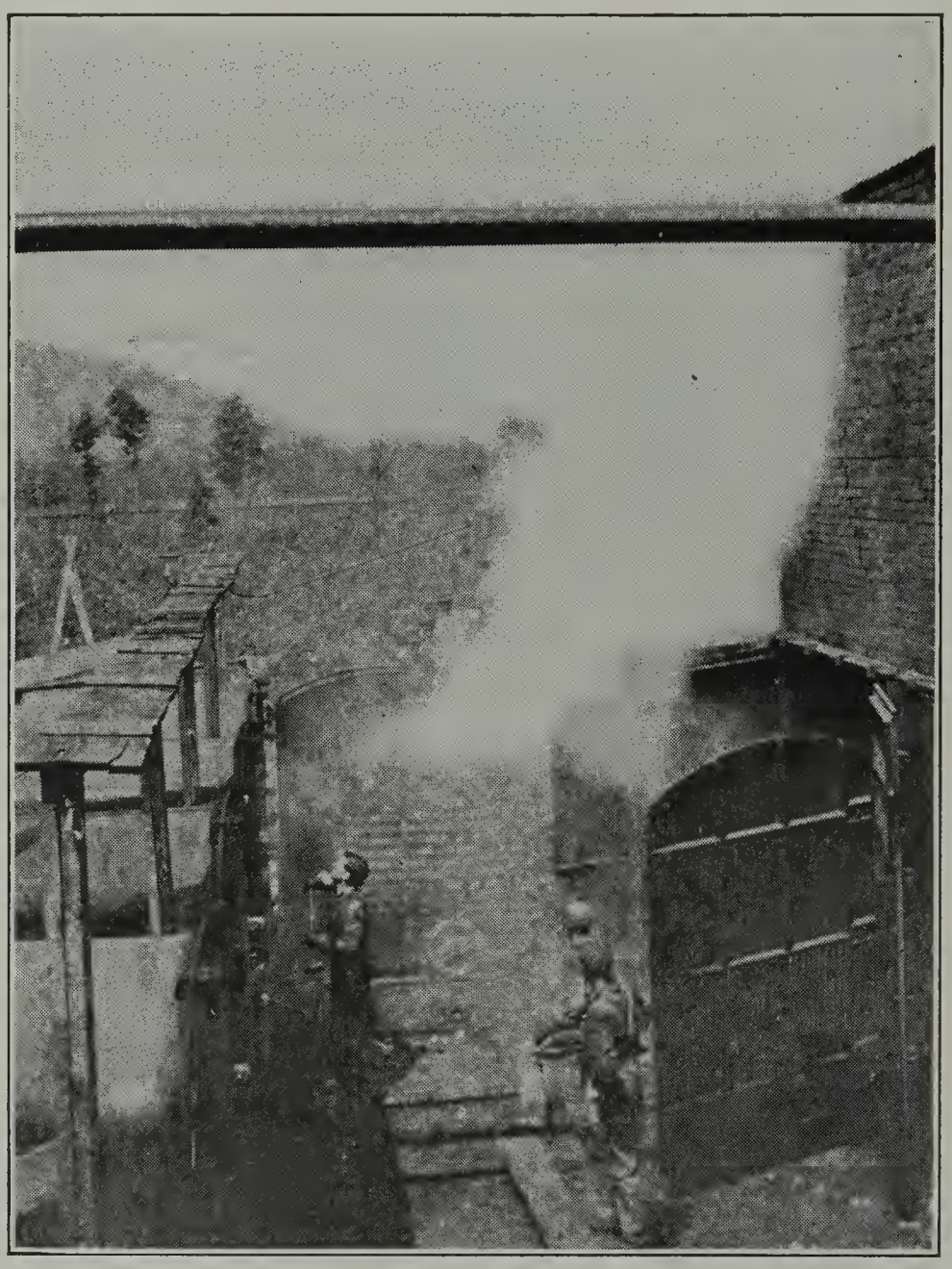
This lack of definite data on a commercial scale, so deplorable in most industries, results from the difficulty of obtaining successive tests with all conditions alike, for we well know that any variation for instance of temperature, has a peculiar relation to the results obtained. In addition it goes without saying that the variety or species of the wood enters largely into the results ob-



Start of Oven Pulling at a Forty Cord New York Plant.

tained, and even the part of the tree used may cause variation. For example, a charge made up wholly of heart-wood will give better yields under the same conditions than a charge of slabs, making due allowance for the bark. Again we have found that weight for weight, cord-wood obtained from the mature or virgin trees will yield higher than the small second growth; also we are convinced of a noticeable difference in results from wood of the same species grown

on high and dry places, and that from low or marshy soil, the latter giving a slightly lower yield. Indeed it is interesting to hear the experienced operator maintain that wood cut in the winter months will give better results than if cut while the sap is running. we are, however, unable to verify this opinion, and it is possible that some other factor may have been responsible for this often

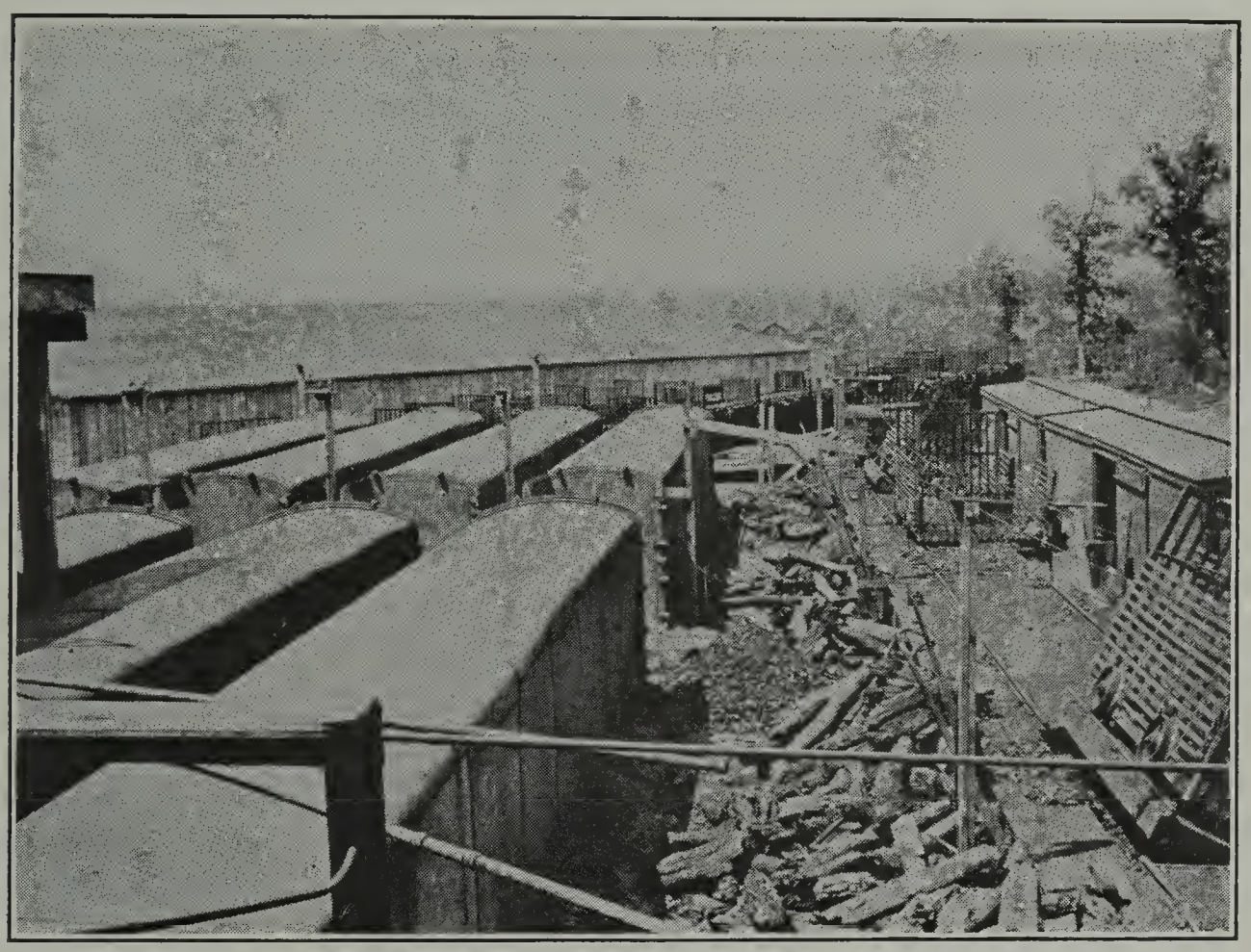


Hot Charcoal Leaving Oven and Entering Cooler.

repeated statement. It is also held by many operators that eliminating the consideration of extra fuel necessary for the charring of green or unseasoned wood, the results are not the same in finished product as from well-seasoned wood. We can see from these statements that with so many factors to be considered, it is extremely difficult to determine which enter most into the discrepancies between the various systems: retort, oven and kiln. However, from

the purely practical standpoint we do know that there is a marked difference between yields obtained from the different systems as well as from the two general localities extensively operating.

If we compare the results obtained by the same system operated in the Allegheny Mountains with that of the Lake Superior region we find that by taking the results on a yearly basis from a well-operated plant and calculating the wood on a basis of a cord 8 feet x 4 feet by 52 inches, there should be obtained conservatively 216 pounds



Series Charcoal Coolers. Twenty-four Hour Charcoal Production on Cars in Background, for Fire Detection.

of 80% acetate of lime, 11.3 gallons of 82% crude wood alcohol and 52 bushels of charcoal. The yield from the Lake district is slightly under this in alcohol, and decidedly so in the acetate yield, which is 175 to 180 pounds on continued operation. However, here again we have at least two factors and it is difficult to determine their relative influence. First, in the eastern field, beech predominates while in the other hard maple is the larger proportion, and also slab wood is used much more largely. In fact, we have been unable to obtain data from a continued operation in which at least a small proportion of slabs was not used.

Construction.

At this point it may be well to take up the question of construction, especially of the most successful and modern system, that of the oven, which is, with the exception of the mechanical manipulation, similar to the retort system.

The ovens are of uniform height and width, in most plants being 6 feet 3 inches wide and 8 feet 4 inches high, the length

Dumping Cooled and Inspected Charcoal for Immediate Shipment.
"Bones" in Foreground.

determining the capacity, running from 26 to 54 feet, and holding from five to ten cords. The steel used in the shell is usually $\frac{3}{8}$ inch, while the bottom and back heads are of $\frac{1}{2}$ inch material. Ovens are built either with doors at both ends in order to withdraw the residual charcoal coincidently with refilling the oven with the wood-loaded cars, or in many cases, with a door at one end, the oven being loaded after the charcoal has been run into the coolers. In any event the door is hung upon a cast-iron frame riveted on the oven. This frame has a groove of about 1 inch for the use of asbestos packing and the cast-iron door is hung to

the frame by riveted cast-iron hinges. The oven is stiffened by means of angle-irons riveted perpendicularly on the sides, and on one side near the top are riveted 30-inch cast-iron nozzles, usually two in number, to which are attached the condensers.

The first ovens installed were placed upon piers in the setting, upon which were iron plates and rollers to accommodate expansion of the oven, but in the later settings the ovens are suspended from tee rails laid across the brick setting at the top and supporting the oven by means of U-bolts riveted thereto. The bottom of the oven

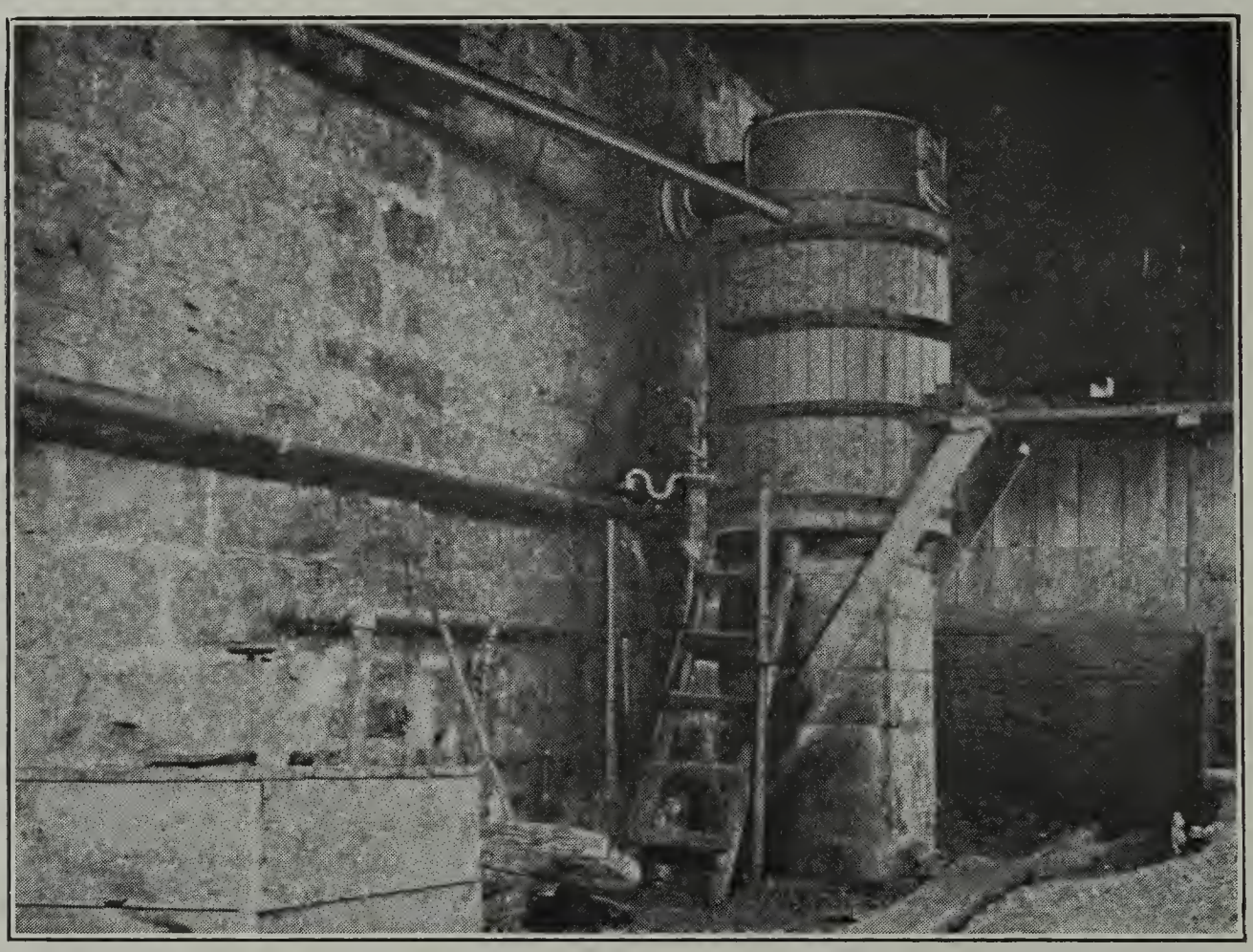
"Bones," or Incompletely Charred Wood, Ready for Redistillation.

is equipped with clips for holding the rails which carry the wood cars. These cars vary but slightly in length in different plants, running from 10 feet 4 inches to 12 feet 4 inches inside length, and about 78 inches high, thus each car holds from two to two and one-half cords of 52-inch wood. Each has four 18-inch wheels with roller bearings running on $2\frac{7}{16}$-inch turned steel axles.

Immediately in front of the ovens are two charcoal coolers arranged in series and approximately the size of the ovens. Into the first the hot charcoal is drawn from the retort, where it stands for 24 hours. From this cooler it is drawn into the second one for

another 24 hours of additional cooling. These coolers are made of very light iron with cast door frames riveted on each end, and light sheet-iron doors. No bottoms are required as the coolers are simply placed on the gound and banked along the sides and doors with loose dirt.

To the nozzles heretofore mentioned are connected the condensers. These are upright tubular condensers, made with copper hoods having a removable head, and are bolted to gunmetal heads



Condenser in Wooden Tub for Side Delivery Oven. Goose-neck and Liquor Run in Foreground.

which are bored for the copper tubes, usually 1¼-inch O.D. seamless copper, and expanded into these gunmetal heads, the whole surrounded by a steel water-jacket with water inlet at the bottom and outlet at the top. Connected to a bottom pan bolted on the lower head is a goose-neck trap for trapping off the non-condensible gases, thus separating them from the pyroligneous liquor, which is run into a wooden tank. The gas from the charge is carried into a main gas line which runs to the boilers where the gas is injected under them by a small steam jet. This jet performs the additional and very important function of serving to reduce any back pressure

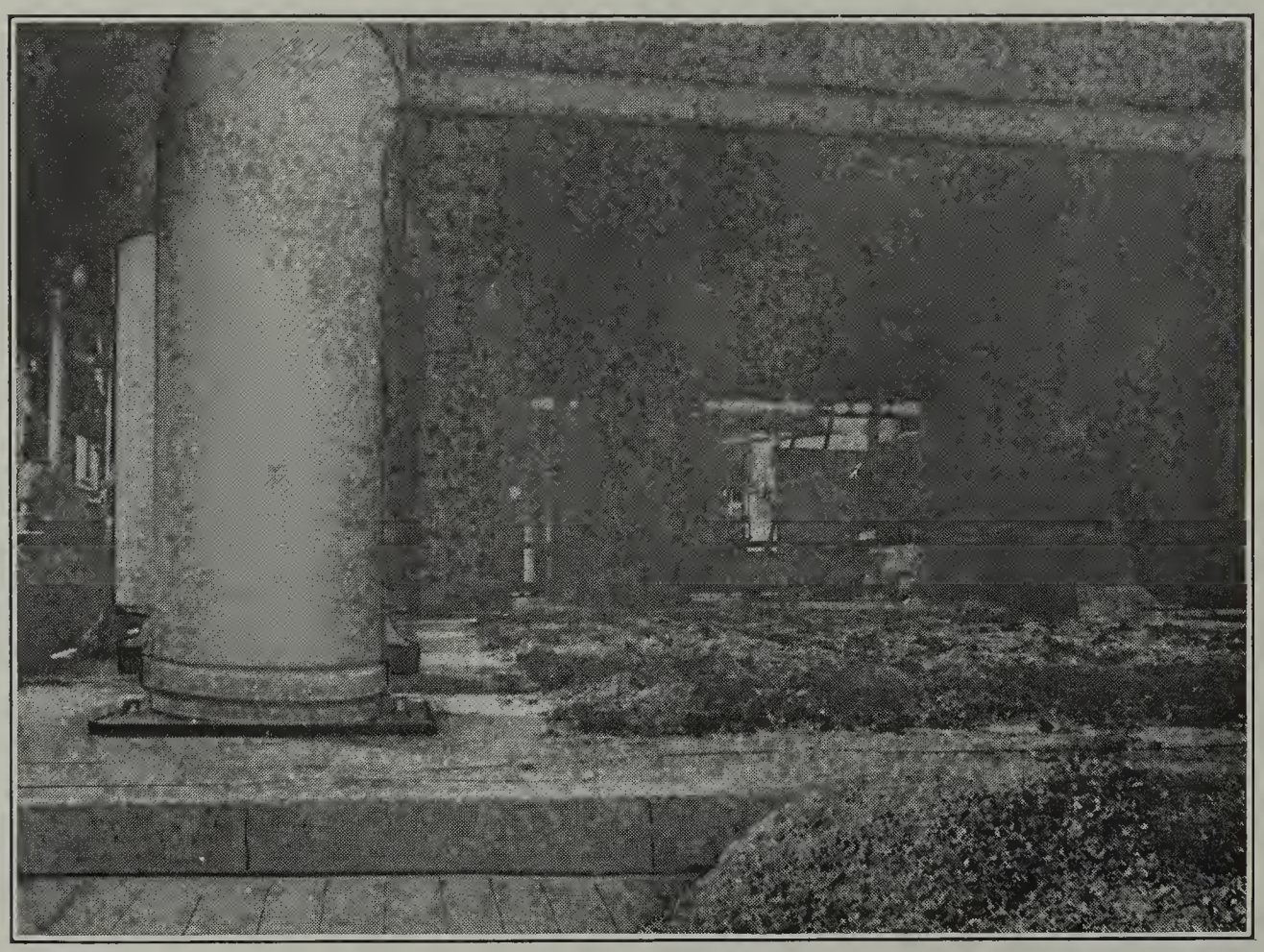
on the ovens, thereby preventing leaks. In order to prevent this suction from becoming too pronounced and drawing over the lighter volatile products through the condenser into the gas line, a butterfly or clapper valve is arranged on the line and regulated by a spring so set that any undue suction opens the valve, thus relieving the line.

Steel-jacketed Side Delivery Oven Condenser.

Primary Distillation Operation.

After this general outline of the first stage of the construction let us follow the operation to this point. After the loaded cars are run into the ovens the doors are pinned shut with taper pins driven into lugs which are a part of the casting of the door frame. The fires are started under the ovens and in about an hour the water distillation and first dissociation begins, the distillate being of a

yellow color, and having a tannin-like odor and running about 2½% of acid during the first hour when well-seasoned wood is used. Gradually this acid content rises until at about the fifteenth hour, when the content should be running from 12 to 14%. After a few hours running, a small percentage of light tar begins to appear and steadily increases until at the latter end of the run, tar is by far the larger constituent of the distillate. The acid content of the watery constituent gradually diminishes until it is almost negligible.

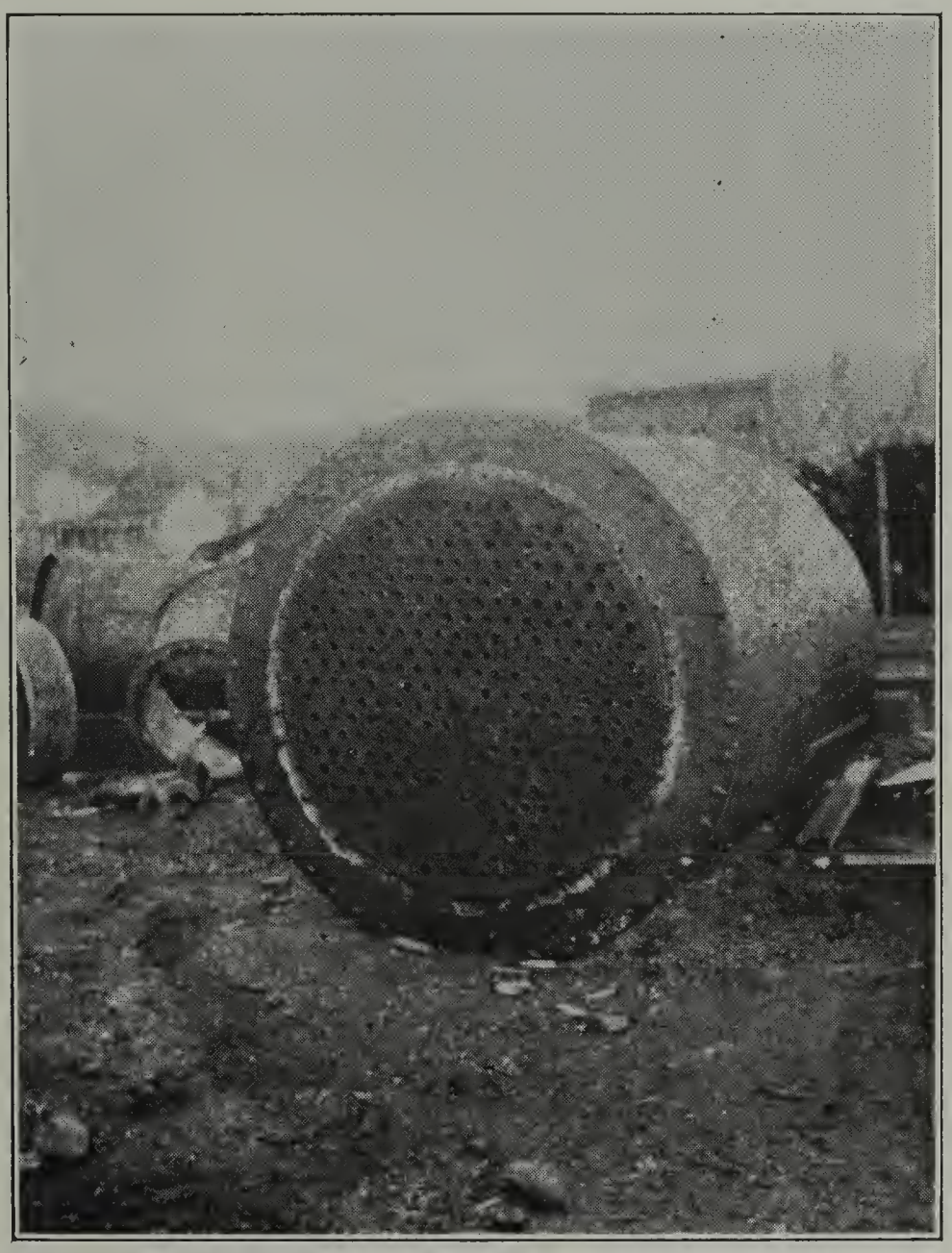


Top-delivery Oven Vapor Line and Condenser on Acetate Floor.

The product obtained under the usual practice, with average wood of at least a year's seasoning, is from 215 to 220 gallons of crude pyroligneous product giving an acid titration of 8 to 8½% and an alcohol content of 4 to 4½%. The tar yield is from 22 to 25 gallons to the cord, with a residual charcoal in the cars of about 52 bushels of 20 pounds each. With green or unseasoned wood the total distillate is diluted and will run from 275 to 325 gallons of liquid.

In the early stages of the run the non-condensible gases are largely air and carbon dioxide. Therefore for the first few hours,

and even after much of the hydrocarbons and carbon monoxide are accumulating in the gases, they have no fuel value. However, the percentage of carbon dioxide diminishes rapidly, and from the middle to the end of the run the oven gas has an important fuel value. The total amount of gas will run from 11 to 12 thousand feet per cord.

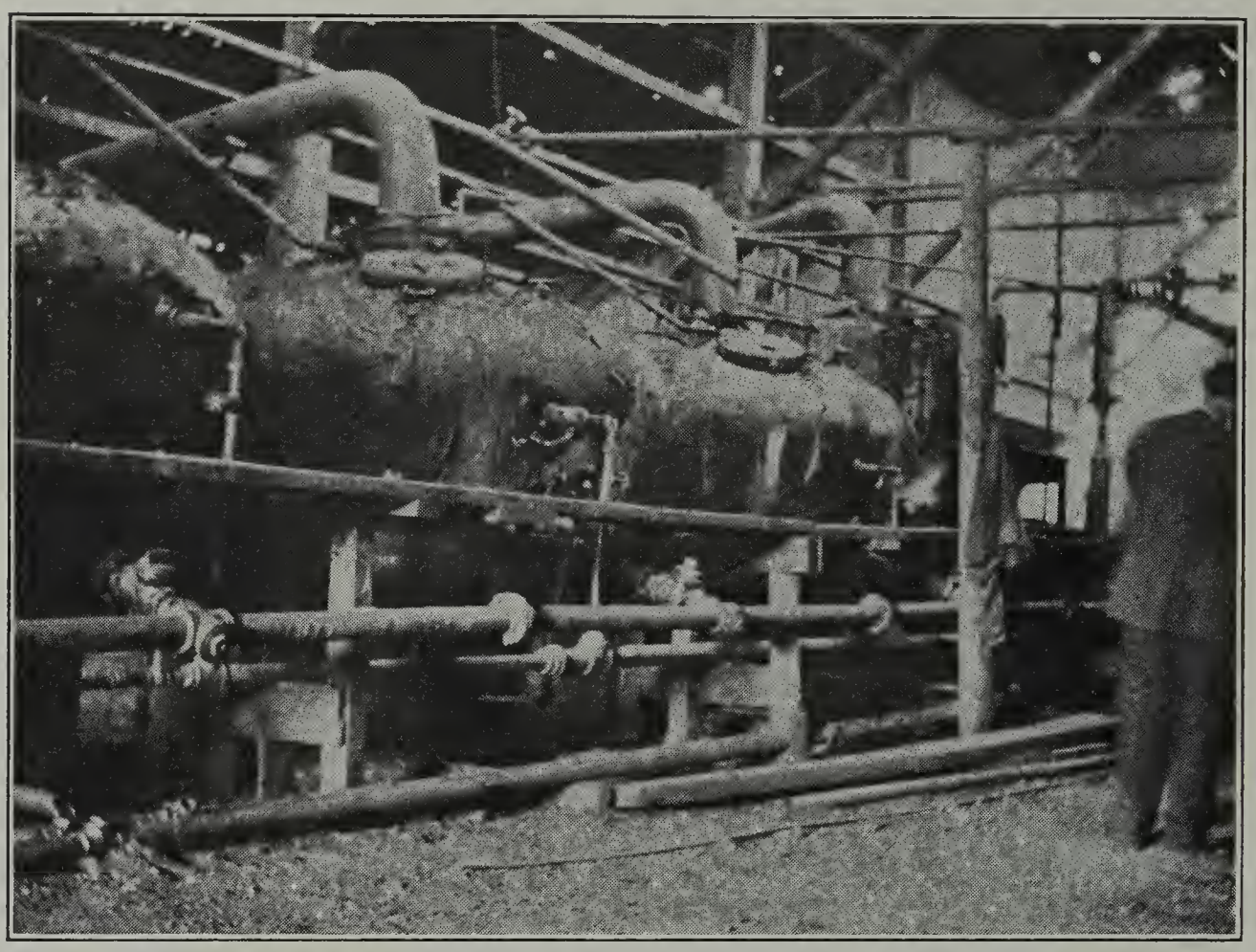


End View of Multitubular Condenser.

As we have already intimated, the influence of the temperature of dissociation is extremely important, and the yields are very dependent upon its regulation. For example, if during the height of the run the temperature at the neck of the oven materially exceeds 750° Fahrenheit much greater volumes of non-condensible gases are being formed, together with an excessive amount of tar, and it is quite possible to lose from 5 to even 10 per cent of char-

coal, together with a serious loss both of alcohol and acid content. Rapid firing, however, without reaching excessive limits will materially increase the acid content at the expense of the alcohol, while slow, even firing, operating the oven at a period in excess of the usual 24 hours will increase somewhat the alcohol production and lessen that of the acid.

The interesting results obtained from excessive firing arises, as we hope to show later, both from a difference in the chemical



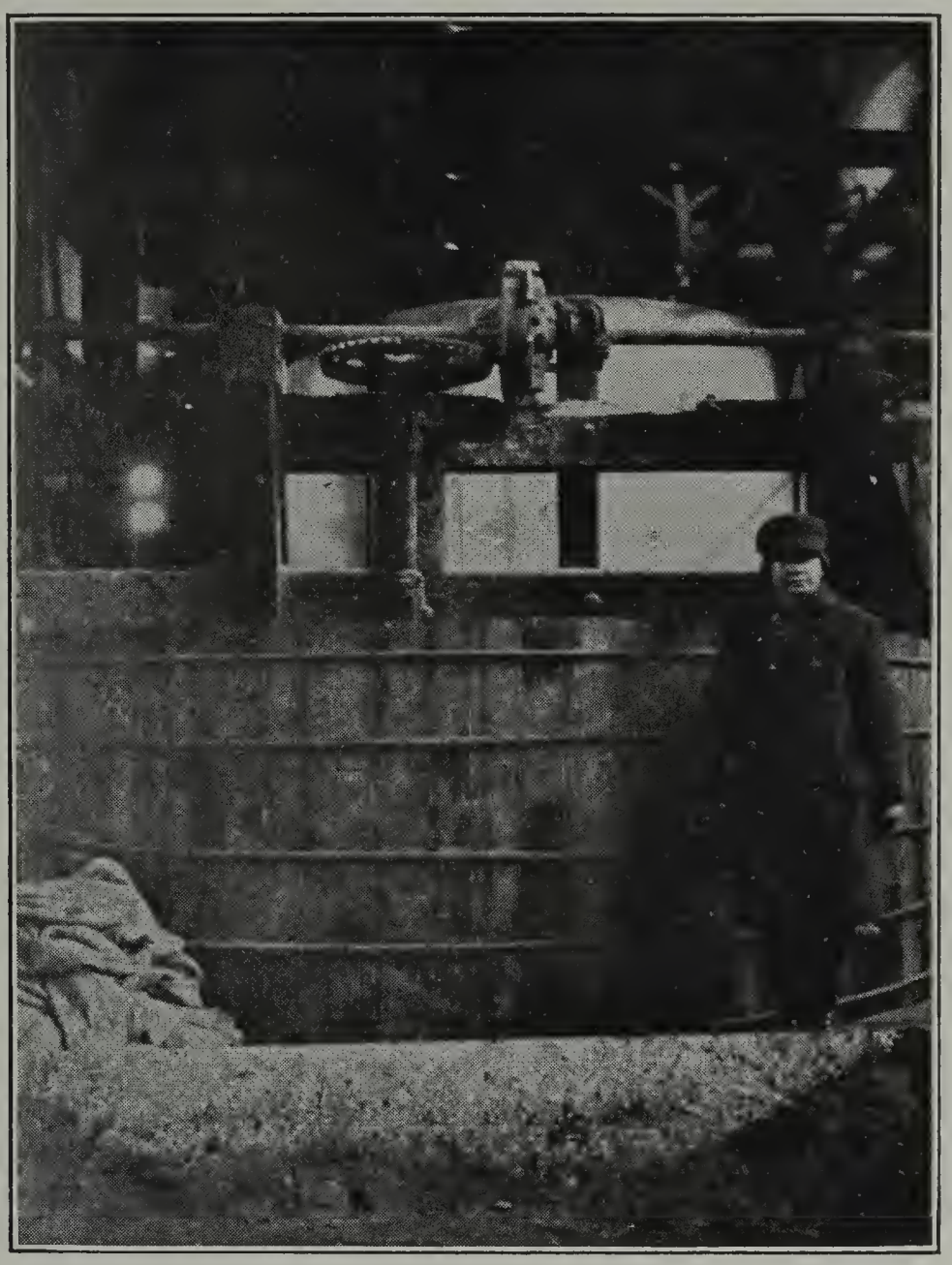
Ancient Type of Copper Stills for Raw Liquor. Formerly Direct-fired, then Converted to Steam Heated, in a Now Dismantled Retort Plant.

dissociation and also from the subsequent formation of condensation products.

In drawing the hot charcoal from the ovens, quantities of combustible gas remaining in the ovens would cause explosion on the opening of the doors. This is obviated by the introduction of live steam into the front of the oven for a short time before the drawing is made.

Handling the Crude Distillate.

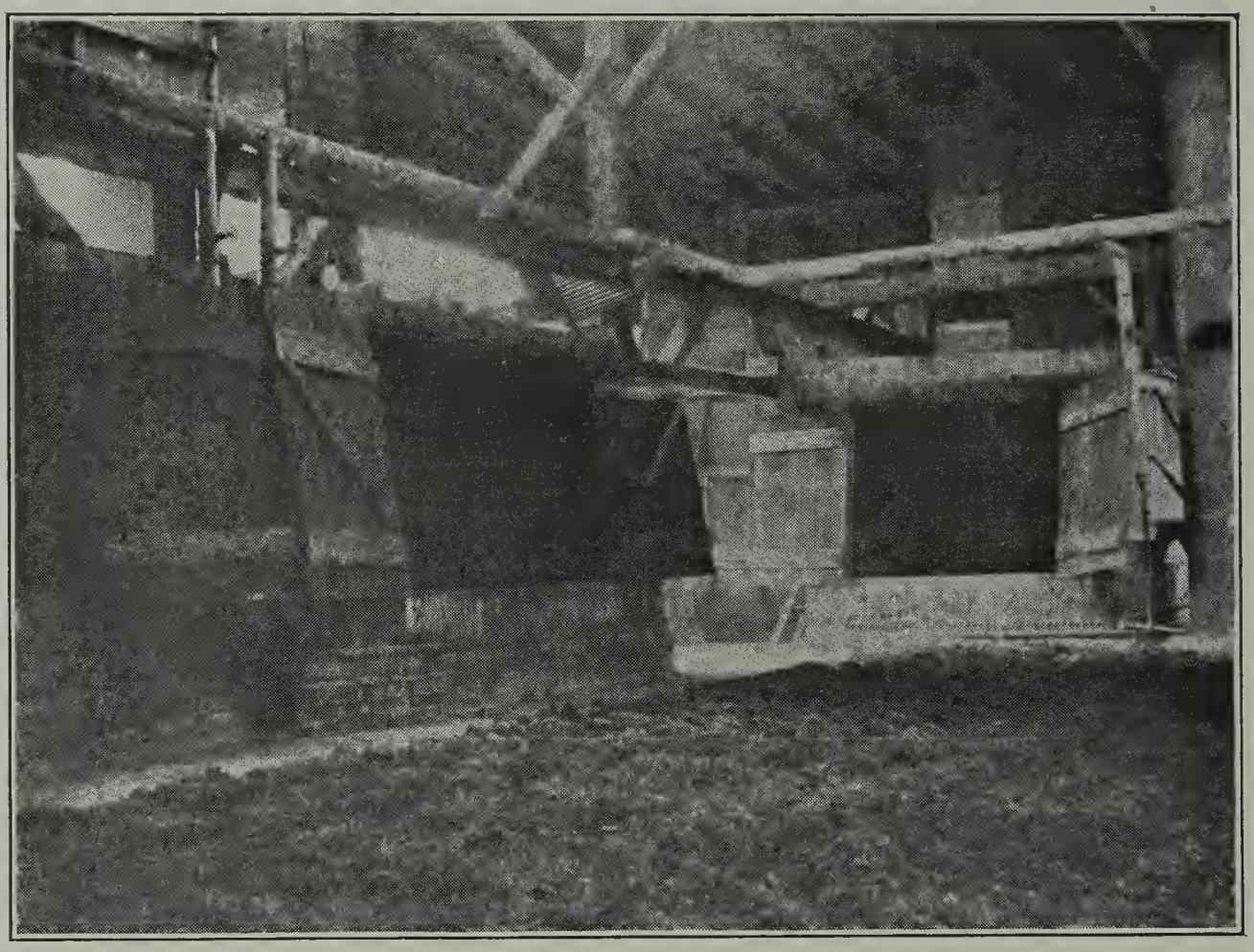
The crude distillate or pyroligneous acid, called in the works "raw liquor," is first pumped into a series of wooden settling tubs, connected with brass piping. The first tub, where the greatest



Mixing Tub for Neutralization of Boiled Liquor. Lime Box in Foreground. Lime Lee Still in Background.

amount of tar settles, is connected near its top with an overflow pipe to the second tub. The second tub is connected with the third by a pipe somewhat lower, and this series of drops is continued so that the last tub is drawn from about within about 18 inches from the bottom. The raw liquor thus settled free from tar is as a rule continuously run into the copper stills. These copper stills are for the purpose of distilling off the lighter volatile products away

from the tars and oils which remained in solution in the settled liquor. They are from 7 to 10 feet in diameter with proportionate height, made of 12 to 14 gauge cold-rolled copper, and equipped with a steam coil, usually of 3- or 4-inch seamless drawn copper tubing and starting from about 18 inches from the top and running helically around the walls and on the bottom to midway between the center and periphery. For a 2000-gallon still from 300 to 400 square feet of heating surface should be used. In addition each



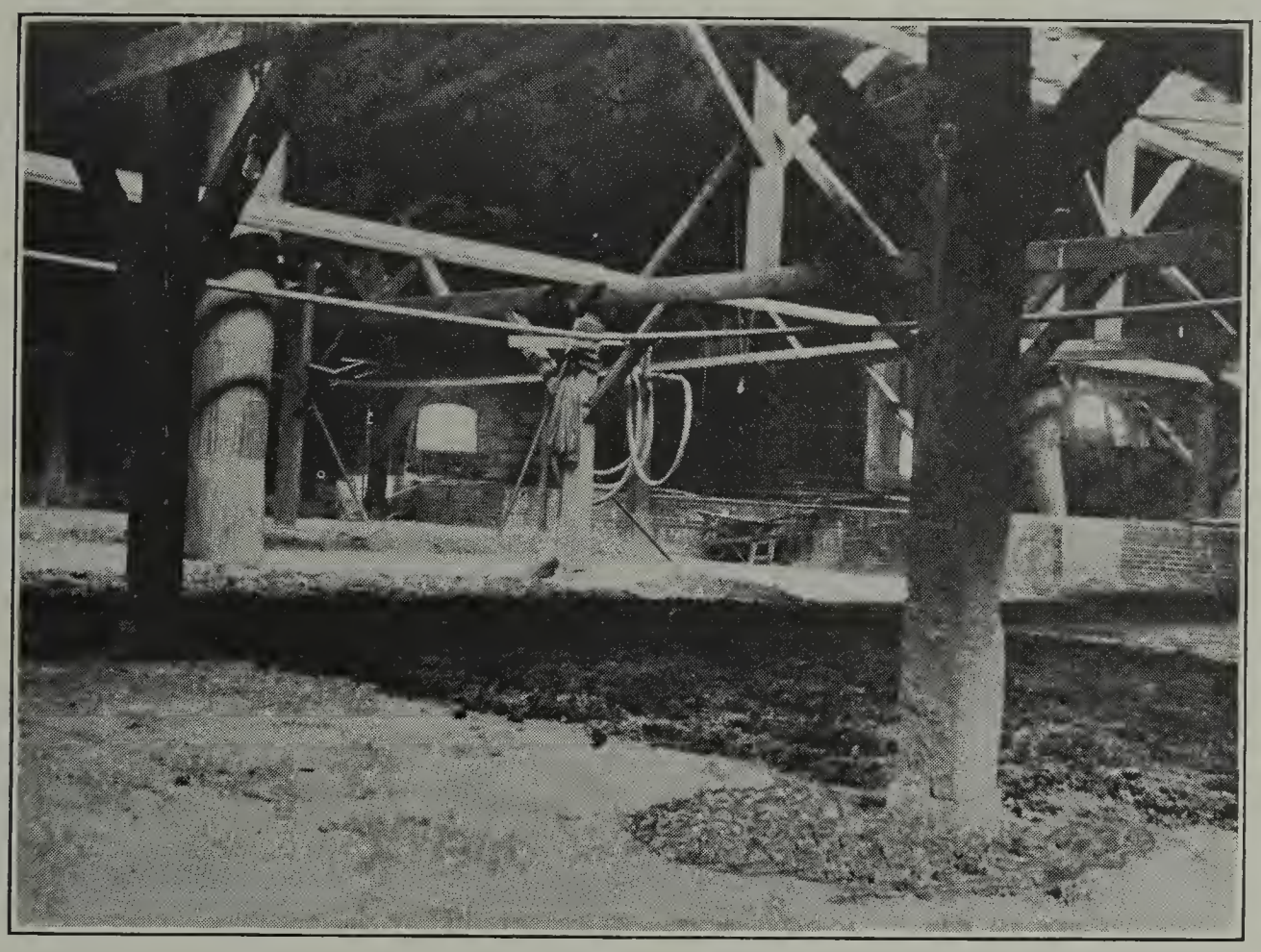
Acetate Pans and Kiln Floor. Partially Dried Gray Acetate in Foreground.

still should be supplied with a live steam jet applied at the bottom and preferably through a copper ring having small steam openings.

After a copper still has run continuously for some time it gradually becomes filled with deposited tar and its flow of distillate diminishes. When this has reached a stage of very slow production, as it does every four days, the feed valve is closed and the live steam jet is opened, distilling the tar with live steam, thus obtaining considerable quantities of acid and light oils. This latter distillate is run into separate tubs, where the light oil on the top is withdrawn before the acid liquor is pumped into the original copper

still distillate, which has been run into a wooden "mixing tub." The tar from the settling tubs is usually distilled in a separate tar still, sometimes made of wood, and distilled as has been that just described. This practice is followed as it permits the separation of the oils independently and without allowing them to come in contact with the original distillate, in which a portion would dissolve, thus the bulk of the distillate contains less impurities by this practice.

The mixing tub is usually from 12 to 14 feet in diameter, and 4 feet high, having a very heavy wooden stirring arm fastened to the

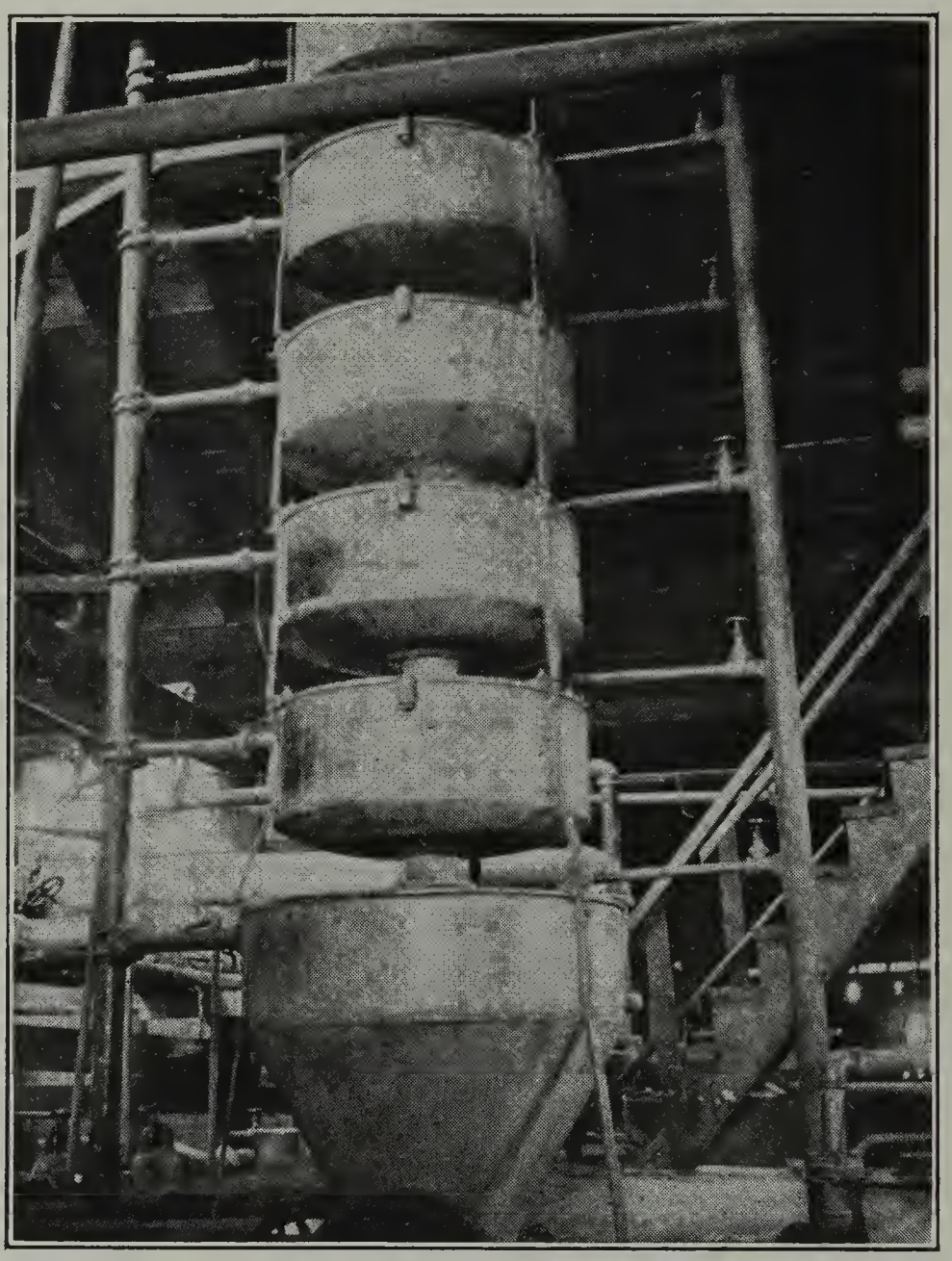


Flue Gas Utilization for Acetate Liquor Evaporation.

end of a heavy shaft, operated by a slow moving gear at the top. Slaked lime is slowly added to the liquor in the tub, which contains its own indicator, the liquid changing at the neutral point to a pronounced wine color. For maximum yields, however, probably owing to the acetic esters present, the addition of lime should be continued until this color has been followed by a yellowish one and until a bead appears or bubbles form on the surface and which disappear slowly. A very small further addition of lime at this point causes the acetate to stick to the pans when evaporated and prevents satisfactory crystallization. Under-neutralization also

causes inferior quality in crystallization, and before final drying the acetate has a decided black color instead of a rich yellow brown, and there is an accompanying loss in product owing to the esters lost.

From the mixing tub the neutralized liquor is jetted or run into an iron still known in practice as the "lime lee" still. In a few



Burcey Pans on Top of Alcohol Still.

plants this is equipped with either Burcey Pans, or, in some more modern works with a fractionating column, although most plants do not fractionate at this point. The customary practice is simply ordinary distillation. The crude alcohol starts over at about 20% on a Tralle scale but quickly rises to 35 and at times 40%, gradually dropping in percentage to from 15 to 20, at which strength it continues for some time and then drops rapidly to 5 or 6%, at which

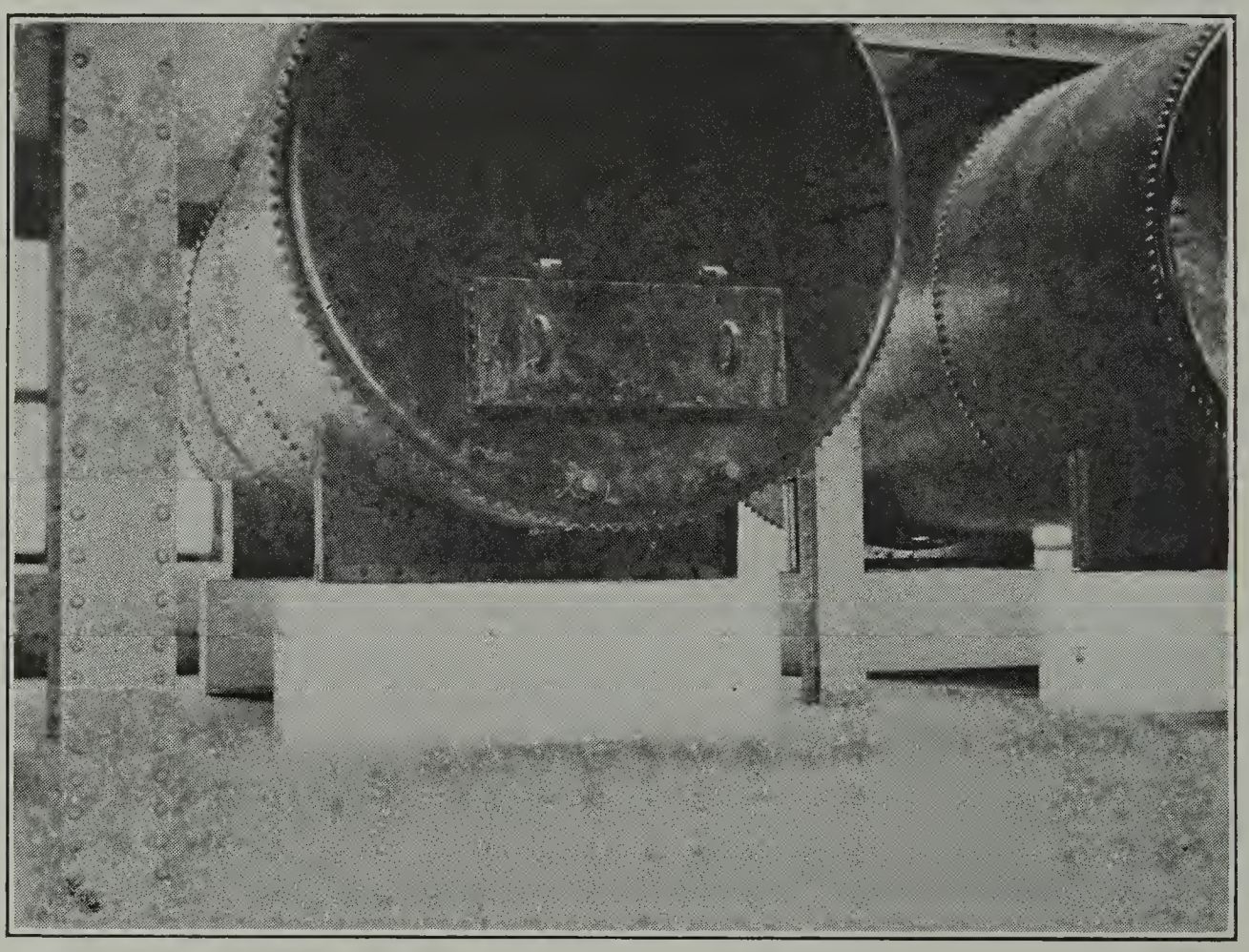
point it seems to hold stationary again for a long period. After all of the alcohol has been distilled over, a valve in the vapor neck is closed and the residual acetate solution is blown, by means of live steam pressure applied in the still, to an iron settling pan above the top of the ovens, where the excess lime and insoluble impurities settle out in a few hours. The acetate liquor is then drawn into flat steam pans having a jacketed bottom for steam supply, the pans usually being about 16 feet long by 8 feet wide and 18 inches

Alcohol Storage and Wood Yard. Log Roads in Background.

deep. Here the acetate liquor is boiled rapidly until crystals appear on the surface near the edges, when the steam is reduced so that the crystalline film which forms at once on the top does not break, which would cause it to fall to the bottom and form a hard crust. Care must be exercised in this "seeding" process as it is called, or a great quantity of this exceedingly hard crust or scale will be produced, which is unfit for the market. After this "seeding down" has continued until the whole mass in the pan has reached a very thick, mushy consistency, it is shoveled out on the acetate or "kiln floor," which is a smooth brick or tile-covered floor over the top of

the ovens. Here the acetate is continually turned until dried and ready for sacking and shipment.

The "weak alcohol" from the "lime lee" still, containing from 9 to 12 per cent of acetone and alcohol, is accumulated and distilled in an iron still having either 5 or 6 Burcey pans, or a column. This distillate is the final crude product produced by the works, and is usually shipped to a central refinery although a few plants refine their own product. In this distillation all the product coming over above 60% is run into the storage tank, and the lower fraction



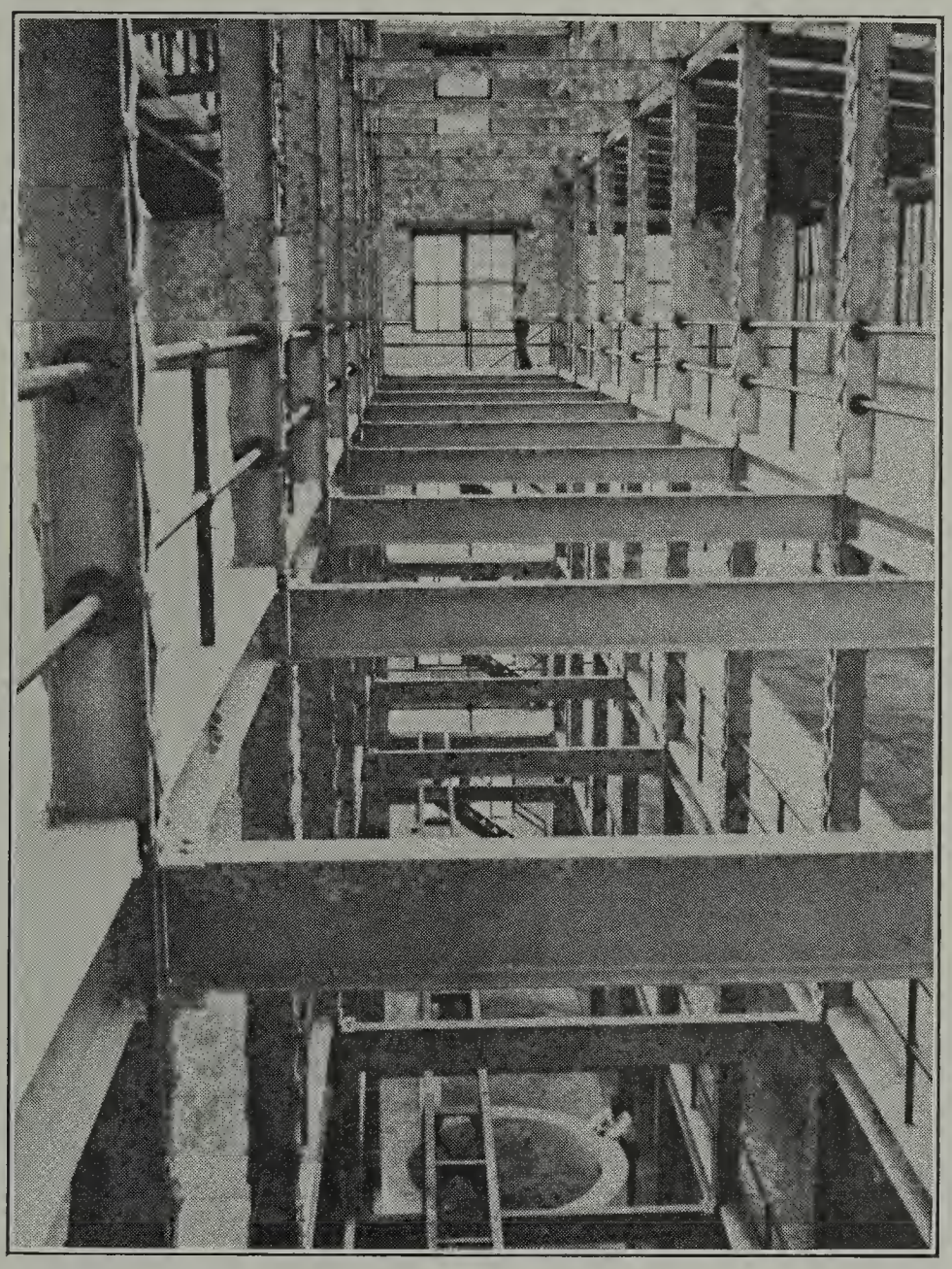
Soda Stills, Wood Alcohol Refinery.

is put back with the lime lee distillate for further distillation. The finished crude is sold on a basis of 82% and contains about 16% acetone.

Returning to the copper still residue, the tar from these stills, as well as that from the tar still, is run into a sump and from there jetted under the boilers for fuel. The two fuel products, gas and tar, furnish approximately 35 to 40% of the necessary fuel for all operations.

Before leaving this subject of operation it might be said that many of the earlier plants omitted this copper still distillation,

neutralizing the raw liquor directly after settling and thereby obtaining the "brown acetate" of commerce, which is to-day practically without market. This brown acetate runs from 60 to 65 per cent acetate.



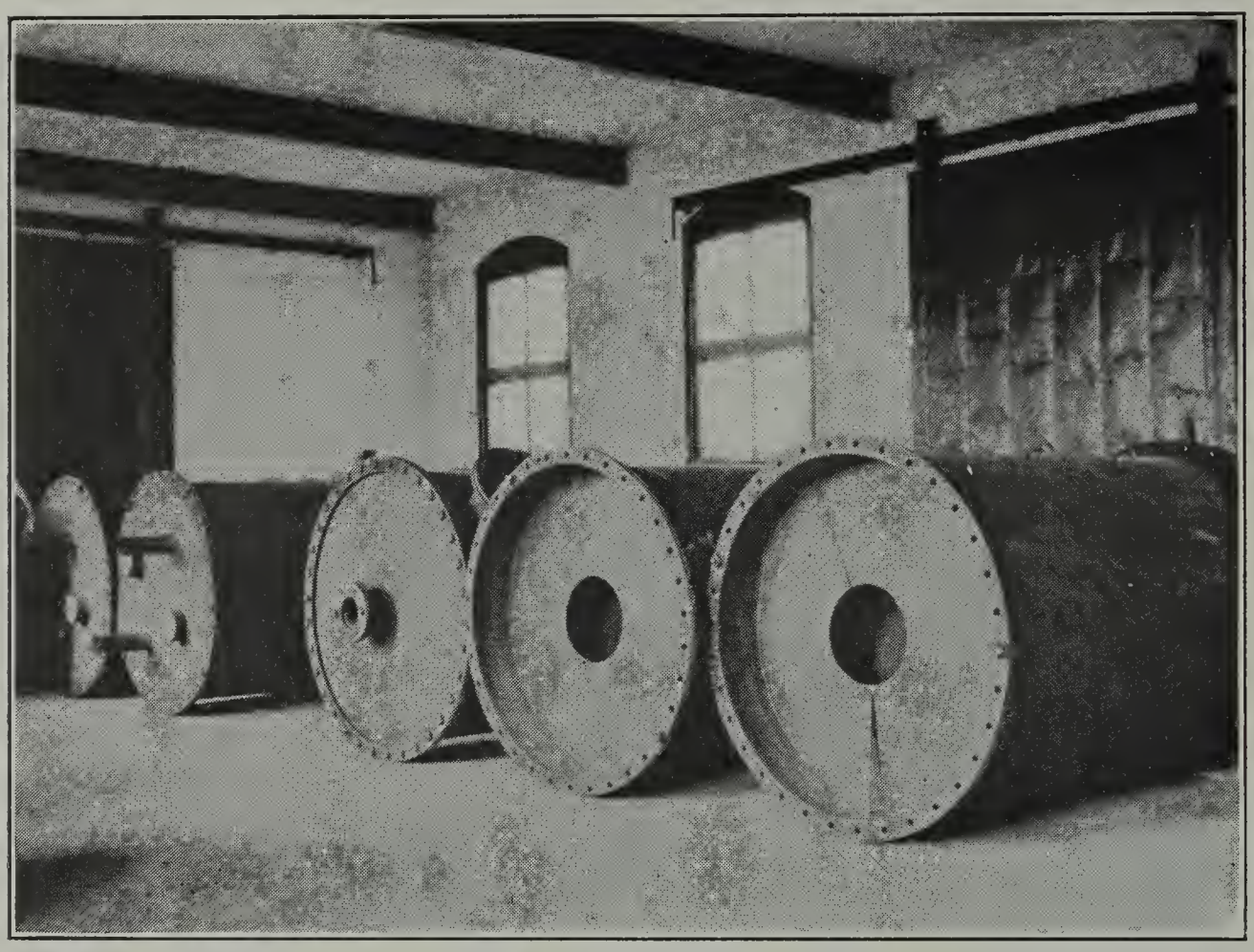
The Column Well in Wood Alcohol Refinery.

Production Costs.

The costs of producing the products above mentioned have been on a constantly increasing scale, owing in a large measure to the increasing cost of cord-wood and stumpage. During the past fifteen years in the eastern district, stumpage in suitable location has been sold for as low as 15 cents per cord, while to-day 75 cents to $1.00 is the approximate average. The cost of cutting varies from $1.15 to $1.35 per cord in fair timber, and in scattered timber $1.50 is

sometimes paid. To-day, including transportation, piling, etc., this will make the cost on board oven cars $4.00 to $5.00 per cord, though wood is being put in for as low as $3.50 by users of mill-waste or by those having long-standing holdings.

This gradual rise in the cost of wood is due to natural causes, among which are the increase in stumpage cost due to the ever-decreasing supply, and the natural rise in labor, together with increased length and cost of transportation. With the exception of one possibility, there appears to be no hope of any future lowering



Column Sections for Wood Alcohol Refining.

of costs. This one exception, a new cord-wood splitting machine, appears from our examination to have merit, and presents an entirely new system of cord-wood production. It is generally conceded that cutting and hauling the large log is less expensive than cutting and handling the cord-wood at the stump. The tree is therefore cut in logs and large limbs and transported to the machine, where a slide carries it first to a cross-cut saw, which cuts it into the proper lengths. The sawed pieces continue to a platform where they are either split in halves or quartered by one blow. The split wood automatically moves by a slide to the railroad car or wagon.

It is claimed that under suitable conditions 50 cents per cord, or in some instances even more, may be thus saved. We have been unable to see continued operations of this machine as yet, and consequently cannot verify this saving cost, but are inclined to believe that at least some reduction in wood cost is possible in suitable timber by this means.

The cost of fuel for a crude works, in addition to the tar and gas used, of course varies with the available supply. In the New York and Pennsylvania districts, when coal is used, this cost will amount on an average to $1.15 per cord, and when natural gas at 15 cents per thousand feet is used, the cost is but slightly more. The labor at the plant is usually counted at $1.25 per cord.

The following summation of production costs will be generally accepted as a fair basis in considering investment in new installations.

Production Costs.

Wood (maximum) per cord	$5.00
Fuel	1.15
Labor	1.25
Lime, 0.96 bu. at 19 cents	.18
Bags (acetate)	.14
Freight (acetate 16 cents per 100)	.35
Freight (alcohol)	.10
Selling commission, acetate	.11
Insurance .068 per cord / Taxes .112 per cord } and General Expense	.57
Total	$8.85

Production Values.

With the present slump in markets the values herein set down are low, especially that for acetate of lime. The past 10-year average would be about $2.00 per hundred, while at present the market is slow at $1.75 per hundred.

Alcohol (82%) 11 gal. at 25 cents	$2.75
Acetate of lime, 216 lbs. at 1.75	3.78
Charcoal, 52 bu., net at 6¼ cents	3.38
Total crude value	$9.91

This gives a production cost of $8.85 and a sales value of $9.91 per cord. It will be noted that no selling costs except in the case of acetate of lime have been included, because in the works not refining

or making the finished products, which are in number far in excess of those that do refine, the alcohol is sold under contract to the refiner, and the charcoal is either, as in the case of those plants in the Lake district, consumed at iron furnaces in connection with the plants, or as in the eastern field handled by a general sales agency controlled by the manufacturers, proportionately to their daily production capacity, yielding to the producer about the above mentioned figure at present.

These production costs are based on the yields in the eastern field, which as pointed out were higher than those of the Lake region. This discrepancy is compensated, however, by the fuel and wood costs being lower in the Lake region, owing to the fact that in most instances mill-waste is used. The general relation between the two fields of operation in this production cost and product value is therefore approximately the same. It is undoubtedly true that many manufacturers can show much greater net profit than the above figures indicate, because of cheaper wood, and fuel and in some instances because of plant design.

Costs of Installation.

Eliminating the cost of wood supply, $2000 per cord per day production, is counted as a reasonable installation cost for a plant as described, for producing crude products. For instance, the cost of boilers, ovens, cars, coolers, pumps, etc., is substantially $650. Copper work, including still, condensers, piping, etc., approximates $450. Brick work for ovens and boiler setting, etc., will come to about $190. These three general items are more or less about a fixed estimate, varying, of course, somewhat upon the price of materials at the time. The location, buildings and general costs vary with the design and the desire of the builder. However, the above stated general figure of $2000 is a fairly accurate estimate, unless elaborate construction is undertaken.

Large Scale Experimentation.

Realizing the possibilities and necessity of counterbalancing the increasing cost of production, several large operators have made extensive large-scale experiments with a view of increasing yields and lowering production costs. Unfortunately the results obtained thus far have not justified the expenditures made, in spite of many

optimistic claims (Met. and Chem. Eng., 1910, p. 434) owing in a measure to the many unlooked-for complications which arise between the laboratory and the works scale. Of the great amount of work which has been done along this line with which we happen to be familiar space permits the citation of but a few illustrative instances.

In the fall of 1908 certain men largely interested in the business went to Germany to investigate developments there and returned with a process for eliminating the copper stills and making gray acetate of lime directly from raw liquor, a proposal which had already been made and studied in this country. This process had been reputed to be in successful operation in Germany. It was in fact merely the application of the cup column to the neck of the ovens. The cups and openings were, of course, of larger size than in the customary column, but in effect this really was all that could be claimed for the new appliance. It was held that the pyroligneous vapors, passing through the condensed tarry liquor, were freed from their impurities by this means and that gray acetate could be produced from the resulting raw liquor by direct neutralization. Educated or impressed by the then incomplete American investigations mentioned, these men permitted themselves to be carried away by the assurances of the German engineers and, as has happened several times in our industrial chemical development in more or less identical circumstances, without any experimental investigation or engineering consideration they equipped a large plant with this apparatus at an enormous expense, the copper work for which alone exceeded $80,000. The plant did not prove satisfactory.

It will at once be seen from foregoing statements in this article, that there were two fundamental reasons which explain, in our opinion, this failure to obtain the desired results. First, as pointed out, mechanical clogging of the apparatus would occur, as was the case in the original worm condenser; and second, as we believe, the valuable products readily form condensation products with the unsaturated hydrocarbons and aldehydes present in the distillate. Certainly the passing of these vapors through the hot tarry liquid would tend to increase this chemical reaction. Moreover, the apparatus caused back pressure on the ovens and required suction to overcome this objection. This increase of suction would tend to bring the vapors through the cups and the condensers at a more rapid rate, which of course would lessen their efficiency.

Later another process, also brought from Germany, was tried, which was in effect the same as the one above described, except that the vapors were forced through a body of hot tar for the purpose of washing them, but this also was not successful. In our opinion this failure was for the same fundamental chemical reason as mentioned above.

A process for accomplishing this result, but not as yet entirely developed, from which some very satisfactory results have been obtained, is based upon a totally different theory from those mentioned. This method places a fractional condenser on the neck of the oven, which is maintained at a temperature sufficient to liquefy the high oiling tars and oils. These, however, are largely mechanically carried along by the uncondensed and non-condensible gases, while a part of the tar is run off through a goose neck on the bottom of the fractional condenser, the uncondensed vapors and the noncondensible gases with their suspended tar and oil liquids are carried into the bottom of a centrifugal basket or drum, installed in a copper container and having small perforations inside of the drum, which is supplied with wings to give a rapid motion to the gases. This centrifugal action throws the liquid particles or mist against the side of the container, on which are deflectors set at an angle opposite to the direction of the moving drum. Thus the condensed bodies are forced to the bottom of the container and out of the zone of circulation, through a goose neck into the tar receiver, while the vapors continue to a second condenser and are there condensed, the wood gas being tapped off in the usual manner.

This process has given uniformly increased yields of product but exact data as to saving, yields and cost of operation have not been determined as yet. A little over one horse-power is necessary for the operation of a 7 cord machine until speed is attained, then ¾ H.P. is necessary.

The increase in product yield with this method is probably due to the fact that the vapor contact with the condensed and unsaturated bodies present is reduced to a minimum.

Another attempt at fuel conservation, which it seems should be possible of accomplishment, relates to the evaporation of the acetate liquor. As has been seen, much heat is necessary for this evaporation, and this method attempts to utilize the high temperatures of the gases at the oven's neck before they enter the condensers. We are not aware of any installation of this nature although patents

have been issued for accomplishing this end. Nevertheless, as it involves what appears to be a wholly mechanical manipulation there should be no great difficulty in saving at least a portion of this waste heat. Here again it can be seen that experimentation to accomplish this end is costly, since all experimental changes necessitate considerable financial outlay if tried on a large oven, and also involve interruption of regular operation which must from time to time inevitably occur.

Under this head of experimentation may properly come an elaborate attempt to utilize hardwood sawdust for alcohol manufacture. This was undertaken in 1903 by a well known lumber company in Cincinnati, who endeavored to destructively distill sawdust continuously by means of an endless belt which carried the sawdust through an oven for the purpose of carbonizing, tapping off the pyroligneous vapors and obtaining an uninterrupted production of charcoal, which was briquetted. The distillate was handled in the usual mnaner.

It can be readily seen that sawdust cannot be destructively distilled in bulk, as is cord-wood, for the insulating space between the particles prevents the heat from going through the mass. This explains the reason for the endless belt.

No expense was spared either in buildings or equipment, the buildings being of stone and the equipment of the best; the whole costing probably $200,000. Notwithstanding this outlay the operation was a complete failure, the plant being dismantled within a year and the buildings used for other manufacture. The high fuel cost in attempting to overcome the resistance to radiation in such a mass was an important item in the high production cost which resulted in the failure. In addition sawdust charcoal is a more dangerous fire-risk than common charcoal, in the handling of which in the ordinary charcoal plant, special arrangements are necessary.

Within the past five years some plants have installed double and triple effect evaporators with a view of fuel economy and reports as to the results are very contradictory, but the continued use indicates at least partial success. One Michigan plant is successfully drying its acetate with a drum and belt dryer. Vacuum drying for acetate has been tried, but we are unaware of any success as the resultant product is a powder while the market demands the crystal.

Refining.

From the time of the formation of the already mentioned Burcey Refining Company, the usual plan of manufacture contemplated only the production of the crude product as described, selling the product, those of the Eastern field, largely to a Buffalo refinery and the Michigan manufacturers to Detroit, and up until the passage of the Denatured Alcohol bill by Congress they received a price usually ranging from 40 to 75 cents a gallon for the crude alcohol. After the passage of this act, and with the purchase of the Detroit plant by the one at Buffalo, the price of crude was at times as low as 15 cents per gallon, and during this period of adjustment intense depression prevailed among the crude producers, as it was feared that ethyl alcohol would largely supplant methyl. It was found, however, that the trade, particularly the paint trade, preferred wood alcohol even at a slightly higher price, and this fact virtually saved the industry. With the formation of a refining company among Eastern crude operators representing somewhat over 1000 cords daily production, and the erection of a refinery at Olean, N. Y., the monopolistic control of refining was immediately reduced. A very acceptable dead rental was paid to the crude producers for their uncompleted refinery, as well as a substantial increase for their crude product, which eventually reached and is maintained at about 25 cents per gallon for 82% product.

The method first employed by refiners was merely that of fractional distillation, and we all perhaps remember the yellow, ill-smelling wood alcohol of commerce. Later, and for a long time, bleaching powder and sulphuric acid were used before the final distillation. This materially improved the product, but with the improvement of the columns used, treatment with sodium hydroxide and distillation is all that is necessary. The NaOH serves the purpose of polymerizing the aldehyde impurities. It also saponifies tarry matter and to some extent the esters. The formerly objectionable acetone present, which distills with the heads, now has its own market value under the name of acetone-alcohol and is used in varnish removers, as a solvent in the rubber and other industries and also as a carrier for acetylene gas in lighting systems. Thus this 16 to 18% of impurity is now in fact an added value to the refiner.

Markets.

Prior to the present unfortunate European situation, the average production of acetate of lime from the manufacturers in this country amounted approximately to 7000 tons monthly, and we are informed that the total European and Canadian production is almost equal to this, of which tonnage Austria-Hungary furnished about two-thirds. The plants in Europe, however, are usually on a very small scale in comparison with those in this country. Sweden alone has plants of a size in any way comparable with the larger ones here. Of the production of acetate in this country, from 50 to 60% is exported, a considerable percentage to or through Belgium. Of course, it will be understood that these statements refer to the market situation before it became demoralized by the European war, although for a year prior to the declaration of war there had been a pronounced stagnation of the markets both at home and abroad.

Of the acetate of lime consumed in this country, by far the largest percentage goes into acetic acid production. The hardwood industry is therefore vitally connected with this acetic acid industry, and one of the most important developments in the last decade is the successful beginning made in combining the crude manufacture and this refined or finished product manufacture in the same plant. Such combination plants have shown crude acetic acid yields in continuous operations running 92 to 96% of theory using 5% sulphuric acid in excess of that theoretically required, and giving on a continued daily production of 4000 pounds per day, with a yield of 91% of the possible theoretical yield, refined acetic acid of the finest double distilled quality.

The chief individual acetic acid market demands in this country are from the manufacture of white lead, paint colors, the textile and leather industries, although in the aggregate the small consumers such as the laundries, ink, photographic, and drug trades, consume great quantities. This country prohibits the manufacture of acetic acid vinegar, but its production is permitted abroad.

The consumption of export acetone produced in this country is chiefly by England. Italy is just now a large consumer. The industry is in a particularly thriving condition at the present time owing to its use in production of explosives for the European war. There should be obtained 20 to 22 pounds of acetone per 100 pounds

of acetate used, and in connection with the crude works acetone production is very profitable, as the general operating expenses are low. Of course its use in this country was very large for explosive manufacture and for the production of chloroform under the well-known Rumpf patents, regarding which there was so much patent litigation some years ago and which as you know were upheld. In comparatively late years, however, a large Michigan concern has produced chloroform commercially from carbon tetrachlorid, which has probably influenced somewhat the acetate consumption for this manufacture. There are 4 plants in the United States producing acetone for the market and within the past week ground has been broken in Pennsylvania for a fifth plant. There is but one plant operating in Canada to our knowledge.

Ten years ago the steel industry consumed by far the major percentage of charcoal produced. This percentage, however, has decreased considerably, owing to the improved methods for steel production. Many industries such as cutlery and car wheel manufacture demanded charcoal iron, but in these and many other instances, coke iron has been substituted. This falling off in the proportionate use of charcoal in iron production has been made up in an increased domestic demand. Charcoal is now sold in small paper sacks in many cities for use both in hotels and private families.

The production of crude wood alcohol amounts to between 10 and 11 million gallons per year, and of course it has innumerable uses, including that of paint industry, which is the largest single user.

Space will not permit in a general article such as this, of going into details regarding production and markets of other products, such as formaldehyde, creosote, etc., which are directly or indirectly derived from hardwood distillation.

Distribution of Plants.

Although not in agreement with any published figures we placed the distribution of distillation plants as follows:

Michigan	8 oven	plants carbonizing	1032 cords daily
	5 kiln		1050
Total	13		2082
Penna.	33 oven		1424
	13 retort		215
Total	46		1639

New York	7 oven	plants carbonizing	256 cords daily
	17 retort		362
Total	24		618
Wisconsin	2 oven		96
	1 oven-kiln		250
Total	3		346
Kentucky	1 oven		20
W. Va.	1 oven		49
Tennessee[1]	1 oven		32
Vermont	1 retort		16

This makes a daily capacity in this country of 2909 cords in 53 oven plants; 593 cords in 31 retort plants and 1300 cords in 6 kiln plants or a total of 4802 cords in 90 plants.

In Canada there are 9 oven plants charring 424 cords daily and one retort plant charring 48 cords or a total of 472 cords in 10 plants. This makes a total for America of 5274 cords per day in 100 plants.

These figures will mean more to us if we remember that 5000 cords of wood represents a pile 4 feet high, 52 inches wide and 7.5 miles long, weighing when seasoned approximately 10,000 tons, thus showing the importance and size of the industry in this country.

Conclusion.

It will be evident that the chief economic drawback in the present manufacture is the fact that most of the plants do not manufacture the finished products, thus in general it may be inferred that two sets of freight charges, commissions and handling expenses are required before the products reach the consumer. For instance, with acetate of lime at $2.00 the net return to the producer is about $1.75 per hundred. A large part of this difference could easily be saved by manufacturing the finished product at the crude plants.

Hitherto such combinations of crude and finished product manufacture have been thwarted in the majority of cases by an almost complete monopoly of the finished products by certain groups of chemical manufacturers, who by various manipulations maintained control of markets, or who were able to dominate the situation, as in the case of acetic acid, by their regional control of sulphuric acid manufacture, or even attempted control of pyrites importation. The

[1] A recently constructed 16-cord retort plant now being converted into an oven plant.

violent market fights which have developed because of these facts have been carried through successfully in more than one instance by the crude manufacturer, because of his advantageous situation, and it is certain that these attempts therefore, to thwart the natural economic development of this industry will sooner or later collapse to a great extent or the refiner will be compelled to either go into the crude business himself or combine with the crude manufacturer.

We have attempted to show the difficulties met and the expensive experimentation that has been undertaken in the past for the improvement of this industry, and have pointed out some of the results thus obtained. When it is remembered that German statistics claim that but one of 15 serious trials of new chemical processes are successful and that this percentage amply pays for the losses entailed in the 14 unsuccessful ones, it can be seen that while these expenditures are individually unfortunate, in the aggregate, this law of averages will probably hold good in the development of this industry for its economic position demands the solution of the problems indicated.

NOVEMBER 7, 1914.

PAINTING DEFECTS, THEIR CAUSES AND PREVENTION

By G. W. THOMPSON

Read at the Philadelphia Meeting, December 4, 1914

When a defect in painting occurs, there are two different attitudes in either of which a person may place his mind. One is to assume that the defect is inherent in the paint used, and the other is to assume that the defect is due to an improper use of the paint. This difference in attitude of mind is not imaginary; it is so real that it seems very desirable that this difference should be explained and amplified.

The principal cost of any painting job is labor, and yet when in the attitude of mind first mentioned, if a paint goes wrong one will condemn the materials used, whereas in the other case he will be inclined to hold that the most costly factor is the one that is probably responsible. It is easier to blame paint materials than it is to blame workmanship. Materials are tangible; workmanship is intangible. Materials can be examined to some extent even long after they have been applied, but there are few means of recording satisfactorily what the workman has done. Every manufacturer of paint feels more or less that if his paint were properly applied it would give perfect satisfaction. Every user of paint is inclined to feel that if he could only get the right material he would be quite sure that he could always do good work.

It would appear that perhaps in most cases the manufacturer is inclined to take one of these two attitudes of mind and the consumer the other, but this is not necessarily the case. Some manufacturers are wedded to certain beliefs with regard to materials, which, judging from their advertisements, one would be inclined to think foolproof, and some few consumers blame their workmen when things go wrong, without thought that the materials used may be at fault.

Without attempting to judge of the relative value of either attitude of mind, as so much has been written connecting painting

defects with materials used, the writer proposes in this paper to take the opposite attitude, and to treat of paint defects, their causes and prevention, not with the idea of connecting these defects to any appreciable extent with the materials used, although he will have to diverge from this rule to a slight extent, but principally to give you the results of a great many years of study of this subject from this standpoint, and to show how paint defects may in many cases be corrected without radical change in the materials used.

In studying a paint defect from the attitude of mind which is adopted in this paper, one cannot, of course, ignore the materials used, but one can seek to find out to what extent such a defect may be the result of the condition of the surface painted, the proportioning of the materials, the application of these materials, the time allowed between coats, etc. From this attitude of mind all of these factors, and others similar thereto, are included in the general term "application." In studying a paint defect along this line, one must use his reasoning powers conscientiously and scientifically. To obtain an intelligent conclusion, he must study many defects; he should furthermore be able to reproduce experimentally the defects being considered before he can reach a positive conclusion as to their causes and cure. It must not be assumed that the writer can explain all paint defects. He makes no such pretensions. But in so far as he is able to speak positively in any case, it will be because he has been able to reason out the cause of the defect, and in most cases he has been able to reproduce the defect experimentally.

A word must be said here in regard to the proper use of painting tests. Such painting tests, in so far as they are of a controversial nature, have not appealed to the writer. The real value of painting tests lies in the information they furnish, in the ability they give the student to classify painting results, whether good or bad. The idea that paint materials can be tested out and their merits determined by a few panel painting tests is, in the opinion of the writer, generally unsound. But if such tests are to be conducted, they should be along lines entirely different from those which have heretofore been pursued, with one or two striking exceptions. The painting of panels indoors and then exposing them to the weather, and from such tests endeavoring to reach conclusions, favorable or unfavorable as the case may be, to certain paints, without prior thereto having determined that the method of testing is a fair representation of what actually occurs in practice, is an unsafe method to

follow. To illustrate this by a parallel case, no chemist would dare to adopt a method of analysis or test that had not been checked up by analyzing or testing mixtures of known composition.

One of the exceptions to which reference should be made is the North Dakota tests. There Prof. Ladd is not satisfied with painting panels and exposing them to the weather, but he also has had a number of houses painted, following ordinary practice. In the case of the North Dakota tests there are actual painting jobs done which serve as a check upon the panel tests conducted under his direction.

Another striking exception is the painting tests on the Havre de Grace Bridge, where the paints were applied both to the bridge proper and to the special panels erected along the side of the bridge. In all cases, if the panels do not confirm the actual service tests, they must be considered only as of secondary value. They have value—but only for the information they give.

This aspect of the subject has been driven home to the writer by the study of many thousands of tests which have been conducted under his direction. He has come to the conclusion that it is very difficult to make a panel test of paint materials which will give results which correspond to the results obtained with those same materials in actual use. The writer did not believe this at one time, and was inclined to take issue with the statement of experienced paint manufacturers, who said that panel tests were of little value as showing the merits of materials when in actual use. A little consideration will, however, show the difficulty of preparing panel tests that will be conclusive as to the merits of paint materials. I refer now to paint materials used for exterior painting. The usual way of preparing such tests is to get nice specimens of wood, paint them indoors, place them on racks between the application of each coat, and when they are thought to be thoroughly dry, they are placed out-of-doors for exposure. The objection to this method of painting is that we never bring a house indoors to paint it unless it be a toy house, and the drying action of the under coats of paint is never the same indoors as it is outdoors. Indoors there is not the same circulation and abundant supply of air that there is out-of-doors. A great quantity of air is needed to dry paint properly for outdoor exposure. Panels painted indoors will not dry so hard as they will when painted out-of-doors. Panels that are stacked fairly close together will not dry so hard as panels spread out and given a great deal of air. We must not think that this applies only

to the outer coat, for that will finally dry when it is placed out-of-doors, but we must remember that for out-of-door work all coatings

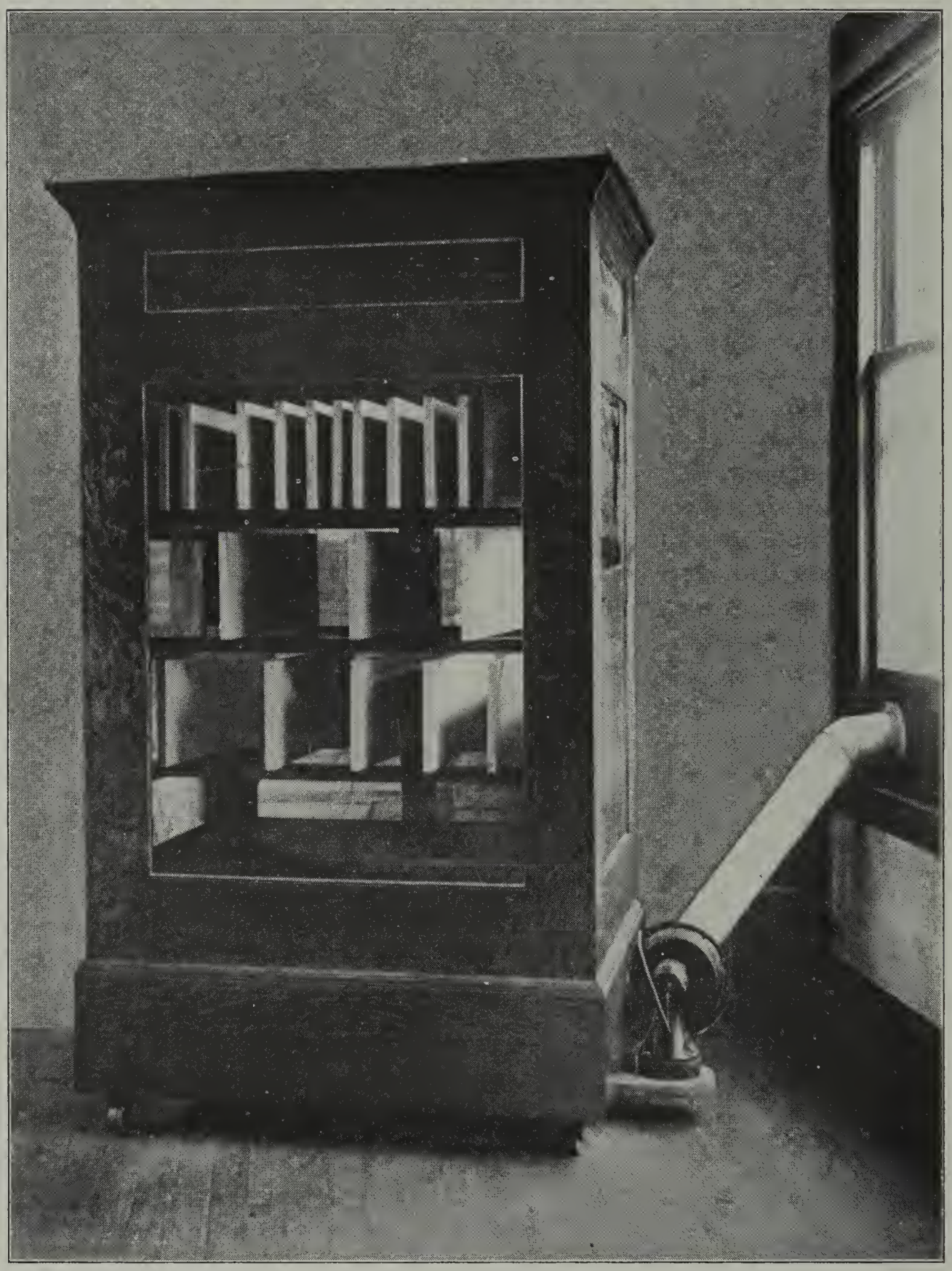


FIG. 1.—Test Board Drying Cabinet Supplied with Clean Out-of-door Air.

are exposed to more or less rapid currents of air, which dry them to a proper condition for durability.

A number of different methods have suggested themselves to the

writer whereby panels painted indoors can be brought to a condition corresponding to outdoor exposure before the actual exposure is made. The writer has thought that perhaps a short heating of the panels after each coat has been applied, at, say, 120° F., might produce results that correspond to outdoor exposure, or that by building a cabinet in which to dry the panels between coats, that cabinet to be supplied with fresh out-of-door air from a blower, he could thereby obtain results corresponding to outdoor exposure. A picture is shown here (Fig. 1) of such a cabinet supplied by a blower with clean out-of-door air. But it is probable that both of these are questionable expedients and that the one way to get correct drying is by out-of-door exposure between coats under conditions where both air and light will be abundantly supplied.

But this is not the only point to which attention should be called with reference to panel tests. Most such tests tend to ignore the modification of composition of the various coats, which the experienced painter finds necessary in order to produce the best results. The principal modification would arise, of course, in the proportioning of the oil and thinner, but sometimes materials are added to paint for definite reasons, and the practical question will always arise whether it is best to add these materials to the first coat, the second coat, or the third coat, and what the quantities to be added shall be. In other words panel tests to determine the value of paint materials should be conducted so as to obtain the very best results practicable with the materials used. This usually involves too much trouble and requires too much experience to satisfy the common demand for quick results.

With this explanation of the plan of this paper, a number of defects will now be considered in the double hope that some light may be thrown on their causes, and that the method of procedure adopted will serve as a help toward the solving of other defects, for the discussion of which the writer has not now the requisite time.

Checking and Alligatoring—The first paint defect to be considered is that described by the general terms, "checking" and "alligatoring." It consists in the development of fine interlacing lines on the surface of a paint, that is, lines embracing areas, which, if small, are called checks, and which, if large, have the appearance of alligator skin. It would appear that the phenomena of checking and alligatoring are closely related and are probably due to the same general cause.

Every varnish manufacturer knows the cause of the alligatoring of varnish. All general experience points to the conclusion that such alligatoring is due to the application of a hard varnish over a comparatively soft undercoat. The alligatoring of varnish is particularly noticeable where cheap rosin varnishes have been used for the undercoat. If varnish is applied over a grained surface, the ground of which is a yellow ochre paint which will not harden

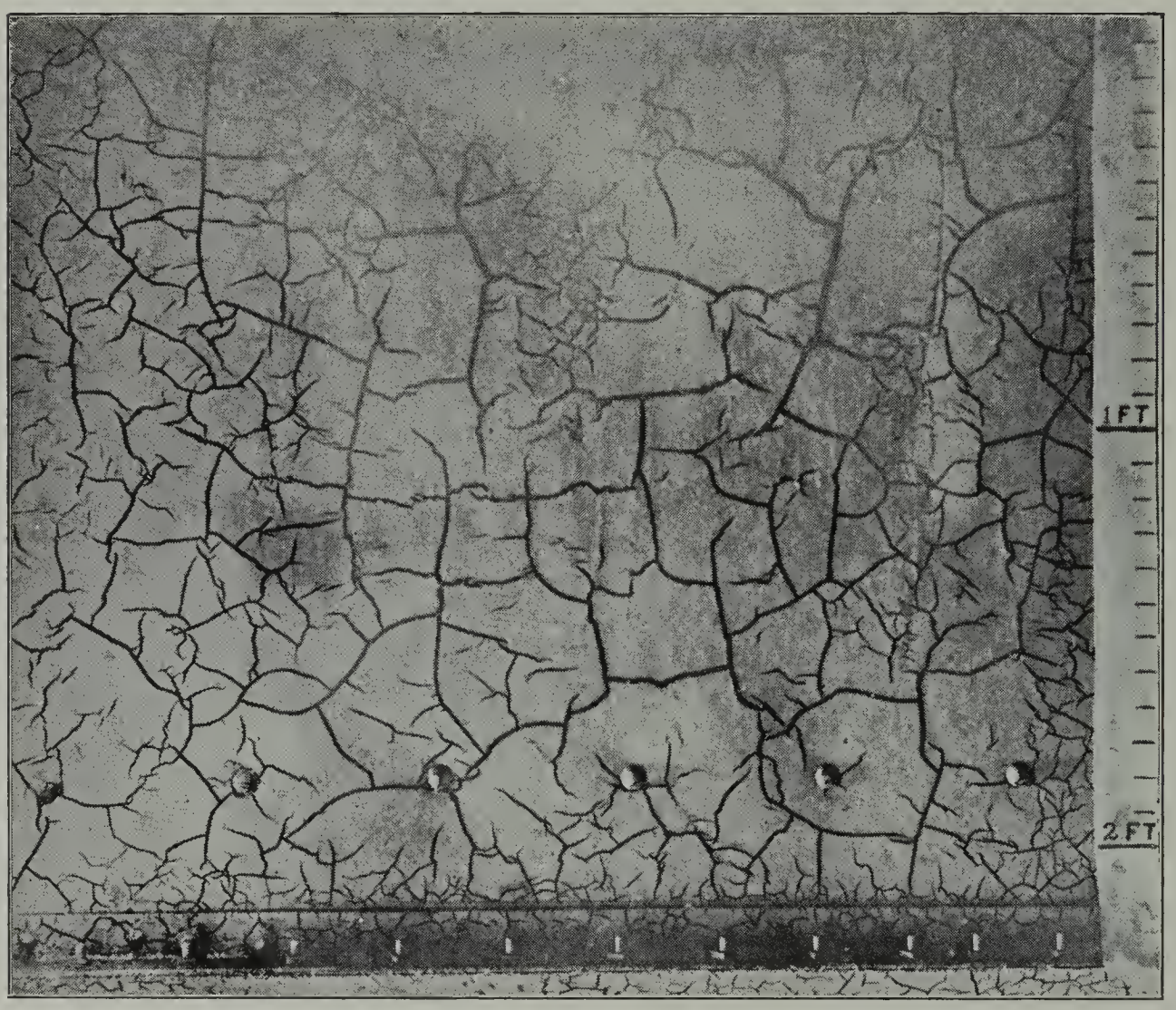


FIG. 2.—White Paint over an Asphaltum Paint.

properly, the surface is quite sure to be alligatored. The reason that alligatoring occurs under these conditions becomes quite apparent with a little consideration. We will take a case of two coats of material applied to a smooth surface. The second coat is applied over the first coat as soon as the latter has dried sufficiently hard. The second coat then becomes dry. Now observe that while the first coat was sufficiently dry at the time the second coat was applied, to permit the application of this second coat, it had not reached what may be considered a fit condition of dryness, that is to say,

that if the second coat had not been applied and the first coat had been exposed to the air, the hardening which is due to oxidation would have continued indefinitely. By applying a second coat, this oxidation and consequent hardening of the first coat has been stopped, at least to a very large extent, but the second coat, on the other hand, can keep on oxidizing and hardening indefinitely, just as the first coat would have done if the second coat had not been applied over it.

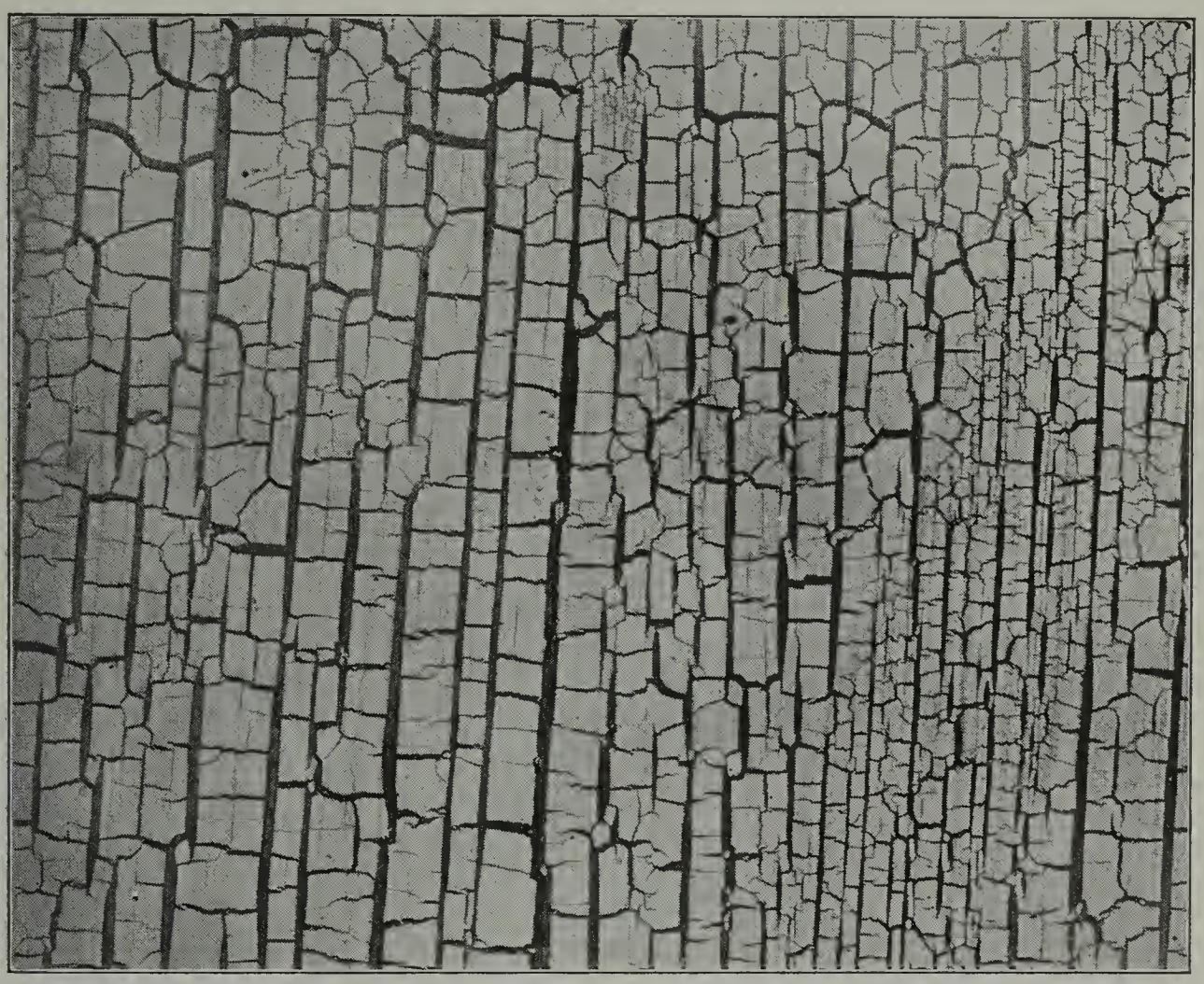


FIG. 3.—White Composite Paint over Ochre Priming.

Now we know that nearly all oleo-resinous varnishes contain drying oils, which have the power of absorbing oxygen from the air, and giving off certain products of oxidation, and the longer a drying oil is exposed to the air the more it becomes oxidized and the harder it becomes. We know also that there is a shrinking in volume during this operation of oxidation and hardening. We know that linseed oil, which is present in oleoresinous varnish, increases in weight through oxidation in the beginning of the oxidizing operation until it has added to its weight up to 18%, but after this maximum

increase in weight has taken place, there is a loss in weight, due to the liberation of volatile compounds, which are carried away in the air, so that after a time a linseed oil film may reach a weight very close to that which it originally possessed. Now during these changes the specific gravity of the linseed oil has increased, from which we must conclude that there has been a reduction or contraction in volume. All this has been demonstrated by the investigations of Prof. A. H. Sabin.

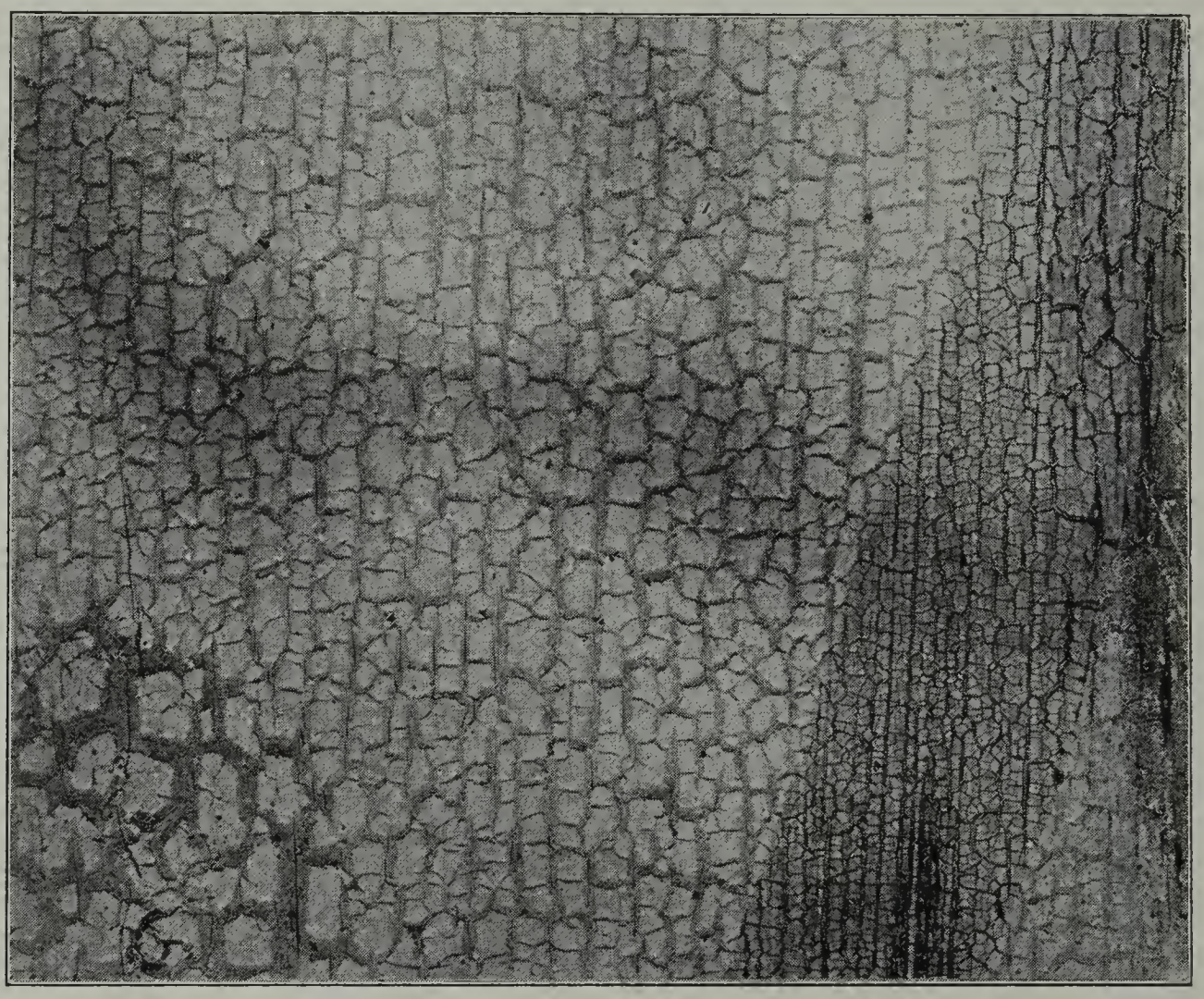


FIG. 4.—Composite Paint over Oily White Lead Priming.

We can readily see how, in the case of one coat of varnish placed over another, under conditions in which the first coat has not had a sufficient chance to thoroughly harden before the second coat is applied, the second coat, on drying, will contract and decrease in volume, while the first coat will remain practically unchanged in its volume and in its degree of hardness.

Now in all cases the outer coats of varnish and paint tend greatly to shrink in volume and to become progressively harder and more coherent, thus producing two possible effects. One of these

possible effects is the rupturing of this outer coat with consequent alligatoring or checking. The other possible effect is that the outer coat becomes thinner without rupturing. Which of these effects occurs depends upon the under coat. If the under coat is soft, the outer coat in oxidizing and shrinking will draw up and slip over it with consequent rupturing. If the under coat is sufficiently hard,

FIG. 5.—White Lead Paint over Ochre Priming.

the outer coat does not slip over it and simply becomes thinner by shrinkage, and no rupturing occurs.

This is the general explanation of the alligatoring of varnish and paint. It is also shown whenever a paint is applied over another paint that inherently will not dry hard, as in the case of a harder paint applied over an asphaltum paint (see Fig. 2), or in the case of a harder paint applied over a yellow ochre paint (see Fig. 3). Very

extreme examples of checking or alligatoring occur where a non-volatile mineral oil has been used in an under coat.

This explanation is one that is quite generally accepted, although there may be minor points on which there is disagreement. Now if this is true, in what way does checking differ from alligatoring? From the writer's experience, the causes of checking are identical

FIG. 6 (×8).—White Lead Paint without Addition of Acetate of Lead.

with the causes of alligatoring, and he has experimentally produced a series of paint defects beginning with very fine checks on one side, and ending up with very large alligatoring on the other side. (See Figs. 4 and 5.) If alligatoring takes place, it simply means that the under coat is relatively much softer than the outer coat. If checks occur it means that this difference in the hardness of coats is not so great as in the case of alligatoring, but the difference is in degree, not in kind.

In order to avoid checking and alligatoring, it is best to seek to have the under coats as hard as is practicable, and to have these coats, relatively speaking, much harder than the outer coats. This is the practice in coach and carriage painting, where very little oil is used in the under coats, and as we know, coach and carriage painting is perhaps the best type of painting there is. Now in the case of house

FIG. 7 (×8).—White Lead Paint with 1% Addition of Acetate of Lead.

painting, suppose we have checking and want to avoid it, how shall we proceed? The answer is inevitable. We must so modify our under coats as to secure a hardness sufficiently greater than that to which the outer coat will attain, and then checking will be avoided. To make the under coats sufficiently hard various methods can be adopted.

The writer would now like to illustrate this matter by referring to

some experiments which he has conducted. Realizing the limitations already referred to as inherent in panel tests, but still believing that they give information of possible value, he had a number of panels painted with white lead, one of which was ordinary white lead alone, and others containing varying percentages of acetate of lead. I show here three photomicrographs (see Figs. 6, 7 and 8), the first with

FIG. 8 (×8).—White Lead Paint with 5% Addition of Acetate of Lead.

no acetate of lead in it, the second with 1%, and the third with 5%. Now you will notice that the white lead with no acetate of lead shows very marked checking, while there is practically no checking in the case of the white lead containing 5% of acetate of lead. Now I must repeat that I do not consider any of these panels fairly representative of good practice. All of these panels were dried indoors, and it is fair to assume that the undercoats did not reach that maturity before exposure that they would have reached if the drying had been

outdoors. This seems to me to be a general defect with panels, the undercoats of which have been dried indoors. Nevertheless, these tests point in a certain direction and are evidence of the soundness of the view which I have advanced, for here clearly the acetate of lead has acted as a hardening agent on the under coats. It is true that the acetate of lead was used in the outer coat as well as in the under coats, but this does not affect the explanation we give of its action, for the hardening effect was relatively greater on the under coats than on the outer coat. These tests are neither an argument for nor against acetate of lead in white lead—they are simply evidence of the idea advanced.

There is one caution I must make here against assuming that in all cases checking is an unmixed evil. I am convinced that in some cases checking is the lesser of two evils, one of which is necessary. You can readily imagine a paint film of so great tensile strength that it will under no circumstances check. Now with the expansion and contraction of the foundation on which such a paint film is applied, trouble is apt to ensue, for if the foundation expands or contracts more than the film, the latter is sure to break loose, and the result is scaling. This indeed would be a more serious defect than checking, and the competent painter must use his judgment in some few cases as to whether he would sooner run the risk of a little checking or take the chance of a more serious trouble.

J. Cruikshank Smith, an English writer, in his little book on "Paint and Painting Defects" thinks that the terms checking and alligatoring, which he says are of American origin, are unnecessary terms, and it would be better to describe them as cracking. Cracking, however, as the term is used here, involves parting of a paint film right through to the surface painted. He says in his book, "Very often it [cracking] is caused by the final coat being less elastic than the under coat, or again, the last coat may have set too quickly, or may have been applied before the previous coat was quite hard."

All this is in line with what we have said before, if we understand that Mr. Smith is referring to the cracking of the outside layer or layers of paint. In regard to varnish he also says, "This [cracking] is due in the main to causes similar to those which govern the cracking in paints or enamel." Speaking of graining he also says, "As a rule graining cracks on account of the graining color lacking elasticity, or because it has not been modified to suit the ground. If the ground is too oily, the application of the graining

color may soften the ground, and unequal expansion and contraction, as between the color and the ground, take place. Cracking will also be induced if the varnish applied over the graining color is too hard and non-elastic."

Now understanding the causes which produce checking and alligatoring, let us see how they can be avoided, going into the matter a little more in detail. Let us direct our attention more particularly to house painting, with which the writer is more familiar. We will assume that the work is to be three-coat work. We have in the first place a priming coat, the main purpose of which is to fill the pores of the wood and to produce a proper foundation for subsequent coats. We have over this a body coat, whose function is to supplement the priming coat and to hide the surface painted. We have finally the finishing coat, which supplements the body coat in that it gives hiding qualities to the paint and also gives the finish that is desired. Reversing our line of thought and starting with the finishing coat, we find that the under coats are for the purpose of giving a foundation to the finishing coat. The priming coat is the first foundation layer and the body coat is the second. Considering now merely the question of checking and alligatoring, it is evident from what we have already said that the priming coat and the body coat must together give a firm foundation for the finishing coat. How shall we obtain this firm foundation? It is the writer's endeavor to avoid a discussion of the materials used except where absolutely necessary. It is, however, important to point out here that no materials should be used in the foundation coats which will not harden sufficiently or which cannot be made to harden by the addition of other materials. It is hardly digressing much from the policy which the writer has adopted to specify two materials which should not be used in the foundation coats. These are such oils or organic materials which have not in themselves the power of becoming sufficiently hard. To be specific, we would refer to all asphaltum, tar or bituminous materials. Furthermore, no mineral oil which is not completely volatile should be used. None of these products hardens sufficiently to give a good foundation coat. Such resinous products as rosin oil, which hardens too slowly to give good results, should not be used. In all paints a drying oil is used. The drying oil should have in a high degree the power of being oxidized into a solid substance. Linseed oil is the principal material used by painters for this purpose, and it should have this drying quality in

the highest degree. The use of linseed oil substitutes which are liable to be deficient in this respect should be carefully avoided. It is important also that those pigments which retard the drying or hardening of priming coats should not be used in excess. This refers particularly to lamp-black and yellow ochre. Other pigments of a similar nature will suggest themselves to you. On the other hand, pigments which assist in the drying and hardening of under coats should be used as far as is practicable.

As we have said, drying oils are essential in paints, but for the prevention of checking and alligatoring no more drying oil should be used in the foundation coats than is necessary for the filling in of the pores by the priming coat and the proper binding of the particles of pigment together in the body coat. By so doing two things are accomplished; one is that the natural hardness of the coating is increased by the increase in proportion of pigment, and the other is that, less oil being used, it takes less time to bring it to a fit condition for the reception of the other coats.

Probably the most important thing to do in the avoidance of checking and alligatoring in the ordinary use of paints is to allow as much time as possible between coats. We have already referred to the work of Prof. Sabin, who has shown that the changes which take place in the drying of linseed oil result in the formation of certain volatile constituents, which should be given off before a paint reaches what has been called here a fit state of hardness. Just how long it is necessary to allow a paint to age between coats, it is impossible to say. If the weather is warm and dry, this fit state may be reached in a comparatively short time. If the weather is moist and cold, it may take a very long time. This suggests a difficulty in obtaining the best results when painting is done in cold weather, when paint dries more slowly. The writer cannot give any time figures here, much as he would like to do so. The important matter, however, is that you should appreciate the reasoning which I have advanced, and with that reasoning in mind, resist the tendency to haste in the application of paint, insisting that the best results can be obtained, particularly with respect to checking and alligatoring, by allowing ample time between coats for each coat to become thoroughly dry and hard.

Cracking and Scaling—The next defects which will be considered are those described by the two words, cracking and scaling. It would appear that these two defects are closely related, that is,

that in many cases scaling naturally follows cracking. By cracking we refer to the formation of hair-like lines on the surface, which an examination shows extend from the surface practically through the paint layer down to the foundation. In this respect cracking differs from checking or alligatoring, which we have described as being superficial, that is as being connected with only the outer coat or coats.

In the case of cracking the areas included by the cracks are usually relatively large, although not necessarily so. In case the painted object is wood, the cracks may be at right angles to or parallel with the grain of the wood. In discussing the question of cracking and scaling in this paper we refer principally to the cracking and scaling of paint which has been applied to wood.

The fact that cracking starts sometimes at right angles to the grain of the wood and sometimes parallel with the grain of the wood indicates that it is probably due to some extent to some action of the wood itself. It is desirable, therefore, that we should know something about the contraction and expansion of wood. Wood contracts and expands with cold and heat, just as most substances do. It is doubtful, however, whether this expansion and contraction with heat is a predominating factor as affecting cracking. This, however, is noticed. Wood is a porous body containing at all times more or less free water or moisture. It has been found experimentally that in the drying out of wood, the greatest contraction takes place at right angles to the grain. Valuable information on this subject is given in Bulletin No. 10, U. S. Dept. of Agriculture, Division of Forestry. On page 37 it states:

"Since only an insignificant longitudinal shrinkage takes place (being commonly less than 0.1 inch per hundred), the change in volume during drying is about equal to the sum of the radial and tangential shrinkage, or twice the amount of linear shrinkage indicated in the table.

"Thus, if the linear average shrinkage of soft pine is 3 inches per hundred, the shrinkage in volume is about 6 cubic inches for each 100 cubic inches of fresh wood.

The reason for this difference in contraction parallel with and across the grain in the drying out of wood is easily understood with a little consideration. The structure of wood is largely fibrous, the fibers running mostly with the grain. Free water or moisture in the wood is probably located between the fibers. This water forces the

fibers apart. As the water dries out, the fibers come closer together, producing contraction across the grain. It would appear also that the variation of the amount of water in wood shows very little tendency to affect the length of the fibers, and so produce contraction and expansion parallel with the grain. It is probable that all have noticed the shrinkage of panels which usually takes place so as to expose the wood parallel with the grain, while very little wood is exposed at the ends of the panels. This drying out of wood apparently occurs even when wood has been painted or varnished, the indication being that even under these circumstances paint and varnish films are slightly permeable to moisture and moist air. So much with regard to the contraction and expansion of wood as affected by its moisture content.

APPROXIMATE SHRINKAGE OF A BOARD, OR SET OF BOARDS, 100 INCHES WIDE, DRYING IN THE OPEN AIR

	Shrinkage, Inches
(1) All light conifers (soft pine, spruce, cedar, cypress)	3
(2) Heavy conifers (hard pine, tamarack, yew, honey, locust, box elder, wood of old oaks)	4
(3) Ash, elm, walnut, poplar, maple, beech, sycamore, cherry, black locust	5
(4) Basswood, birch, chestnut, horse chestnut, blue beech, young locust	6
(5) Hickory, young oak, especially red oak	up to 10

Let us now consider what takes place in a paint film itself. I have already referred to the fact that linseed oil on drying shrinks in volume. It would appear, however, that the shrinkage of paint films is not due simply to the shrinkage in volume of linseed oil in drying. Wherever there is a chemical reaction between the pigments of a paint film and linseed oil or any of the other paint constituents, which chemical reaction results in the formation of new chemical compounds such as soap, there is still further contraction due to the condensation which takes place with the formation of these compounds. Unfortunately we have no definite figures as to what this condensation or contraction amounts to. It probably differs with every reacting pigment, so that some pigments will produce a large contraction and others a slight contraction, while in the case of pigments which do not react chemically on the oil, there is probably no contraction due to this cause.

Now let us think of a paint having this quality of contracting

due both to the oxidation of the oil, and to the reaction of the pigment upon the oil, as applied to a wood which contains moisture. The wood dries out and contracts across the grain, while there is very little contraction with the grain; at the same time the paint contracts both across the grain and with the grain. If the contraction of the paint equals in all respects the contraction of the wood on drying out, there should be little tendency of the paint to crack.

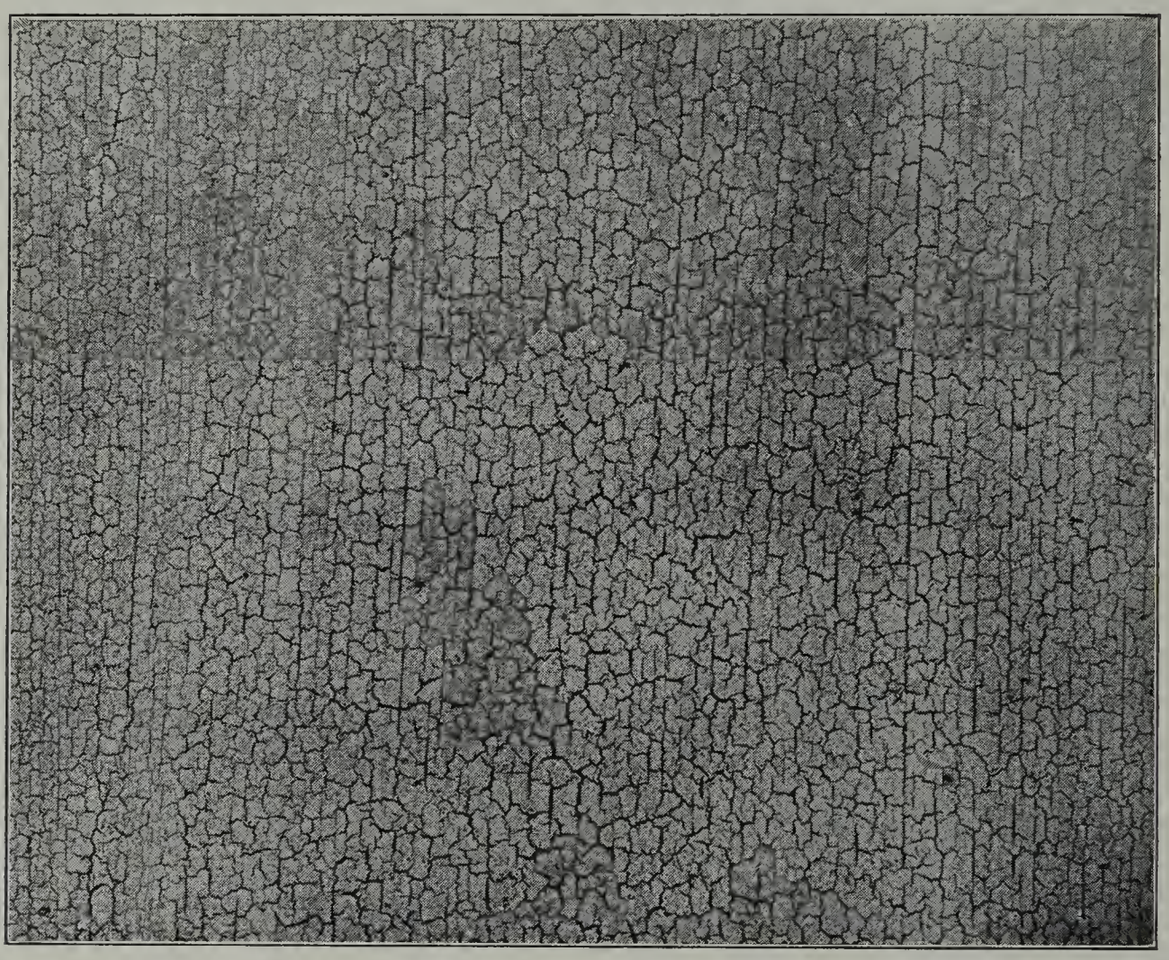


FIG. 9.—Cracking and Bulging of Paint Probably Due to Excessive Contraction of the Wood.

Wood, however, as we have shown, contracts mostly across the grain. Consequently, if the paint contracts across the grain less than the wood contracts, there will be a bulging and consequent cracking of the paint with the grain. (See Figs. 9 and 10.) The reverse condition is also possible but not probable, that longitudinal cracks may occur, due to the paint contracting more than the wood. On the other hand, the contraction of the paint with the grain will not be compensated by a similar contraction of the wood, and cracks may appear, the lines of the cracking showing across the grain (see Fig. 11). This is the rational explanation of cracking. It is as-

sumed, of course, when cracking occurs, that the paint has very little elasticity, is very hard, and is high in tensile strength. The size of the spaces enclosed between the cracks is largely dependent upon the tensile strength of the paint film. If the tensile strength is high, the distance between the cracks will be greater than if the tensile strength is low.

Now what is the relation between cracking and scaling? Cracks, as we have referred to them, extend down to the wood. As soon as cracks occur, there is an opportunity for moisture to enter the wood.

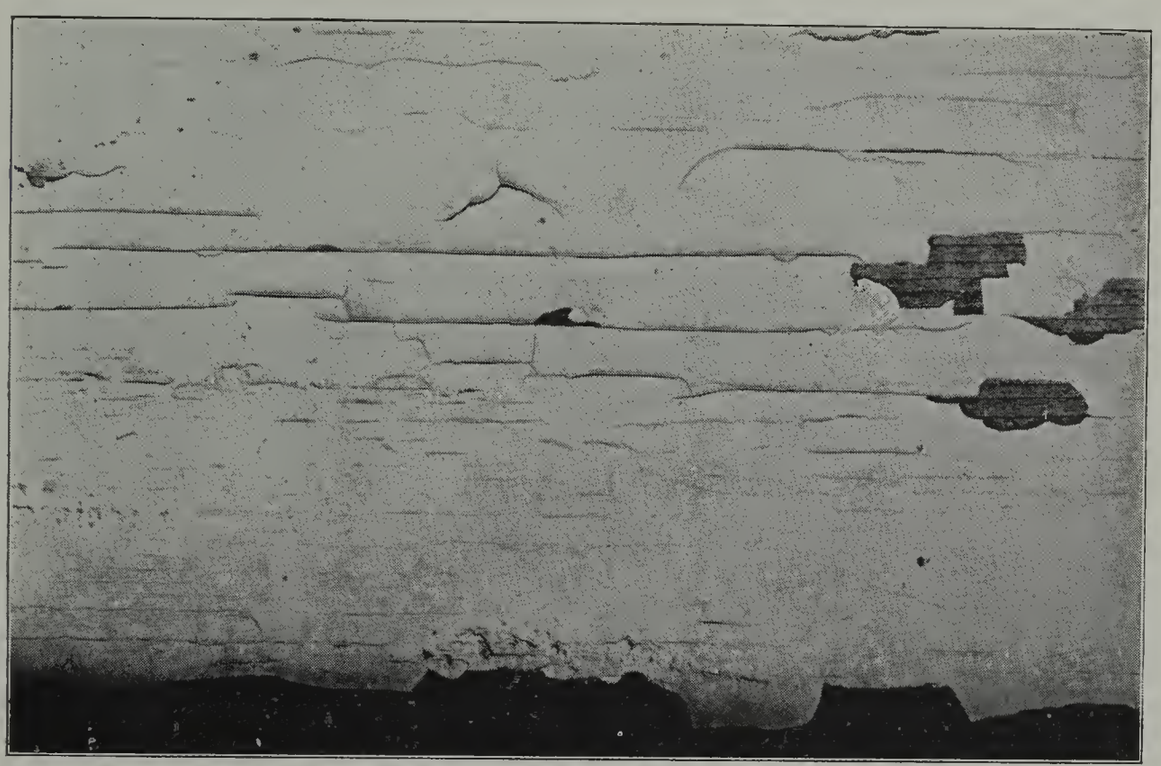


FIG. 10.—A Bad Case of Cracking Showing the Bulging at the Longitudinal Cracks.

This moisture entering by the cracks, travels under the paint film, exerts a pressure against the paint film, the bond between the paint film and the wood is weakened and scaling results.

Further on in this paper blistering and peeling will be spoken of. It seems to the writer that there is a difference between peeling and scaling. Both are due to moisture forcing the paint film away from the wood. Peeling, however, is due to the presence of moisture under an unbroken paint film in the wood or back of the wood, which forces the paint away from the wood. But in the case of scaling the moisture enters through the cracks and travels under the paint film, causing the scaling.

We now come to the question of the prevention of cracking and scaling. It is to be noted that as a rule cracking and scaling take place most often when the paint film is thick. It may not occur on the first painting job, but when the work is repainted, cracking and scaling occur. The reason for this is obvious. The thicker the paint film, the stronger it is, that is, the greater its tensile strength, and it cannot conform as readily to the changes in the shape of the wood. One method of prevention, therefore, is to avoid the accumulation of paint coats upon a surface. If the surface needs repaint-

FIG. 11.—A Bad Case of Cracking and Consequent Scaling, the Cracks across the Grain being Characteristic.

ing, as much of the old paint should be sandpapered off as is necessary, provided, of course, it is too thick, and the new coats of paint applied should be comparatively thin. This refers particularly to paints which are naturally inclined to crack and scale. It is obvious, of course, that those pigments which give hard, strong and contracting coats, should be used only in moderation. Just what moderation is, can only be determined by conditions. It is impossible for the writer to offer more definite advice than this. There are some cases, however, where the painter is in a dilemma. If he wants to prevent cracking and scaling, he can do this only by allowing a certain amount of checking. Reference has already been made

to this difficulty. Hard undercoats tend to prevent checking, but too hard coats generally favor cracking and scaling. Soft undercoats favor checking, but tend to prevent cracking and scaling.

We must suggest also that cracking and scaling can be to some extent avoided by having the wood thoroughly dry and contracted before painting.

I wish I could explain here the scaling of paint on galvanized iron. I regret to say that all attempts at explanation have so far failed. I have found paint scaling on galvanized iron with every precaution taken to prevent it. Galvanized iron has been washed with acid, with alkalies, and with special galvanic primers, such as acetate of copper, etc., without, however, preventing scaling. The scaling on galvanized iron is evidently due to the impossibility of securing a proper bond. It is more apt to occur with hard or thick coatings than it is with more elastic and thin coatings.

Blistering and Peeling—As already indicated, it is hardly necessary to say much on the subject of blistering and peeling. These defects are due to the water in wood forcing its way through the wood to the surface, and breaking the bond of the paint and forcing it away from the surface. Blistering is very apt to occur where moist painted wood is subjected to heat such as the heat of a radiator. Sometimes the heat of the sun is sufficient to increase the vapor pressure of the water enough to produce blistering.

Blistering and peeling are more apt to occur if a very impermeable paint is used. Painters sometimes complain that boiled linseed oil favors blistering. If this is so, it can only be due to the fact that boiled linseed oil gives a more impermeable paint. If one paint tends to blister more than another under similar conditions, it is probable that the paint which tends more to blister is the more impermeable. The one safe method of preventing blistering is to remove the cause, that is, the moisture in or back of the wood. In cold weather wood may appear to be dry, and yet contain a great deal of moisture, which, on a warm day, will force its way to the surface. If one is in doubt as to the condition of wood for painting, the best practice is to allow considerable time after the priming coat has been put on before applying the body coat. It would appear in general that paint allows moisture to pass out through it to the atmosphere more than it allows moisture to pass the other way. This is probably largely due to the fact that we generally have more dry than moist weather. If a priming coat

is applied in this way, it will allow the wood to dry out and to a certain extent will prevent the moisture in the wood from being increased from external causes.

The practice of applying backing paint to window frames, and in general on wood apt to become moistened on the inside has for one of its objects the prevention of blistering and peeling.

Blistering on iron and steel is due to a different cause. Here it generally results from the formation of gaseous products under the paint, due perhaps to the corrosion of the iron, which forces the

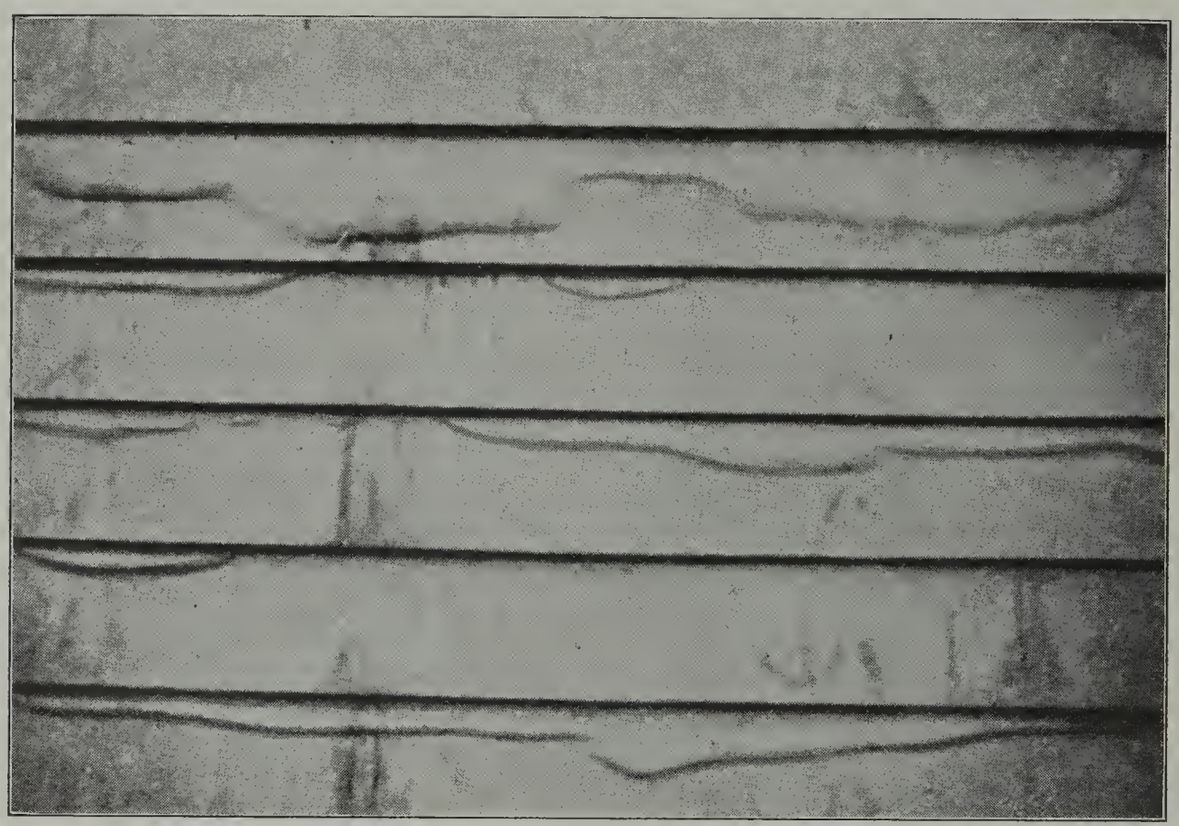


FIG. 12.—Blistering on Top Coat only. The Blisters are Full of Water.

paint from the surface. Sometimes peeling will occur on enameled surfaces which have been painted without proper care being used to roughen the surfaces so as to produce a proper tooth. Sometimes peeling will occur when a paint has such rapid drying qualities, that when applied over old work, the paint dries before the oil in it has had a chance to soften up and combine with the old paint surface.

There is another kind of blistering and peeling, to which I will refer only incidentally, without attempting to explain it. Sometimes it has been found in the case of a recently painted house that after a heavy rain storm, large blisters like those shown in Fig. 12,

make their appearance. These blisters are filled with water, the water being, as a rule, between the coats of paint. The under coats of paint are in sound condition, and it is impossible to conceive of the water having come from the back of the paint. The probabilities are that the water passed through the outer coating of paint by some system of diffusion and collected under it.

Loss of Gloss and Chalking—The chalking of paint is one of those problems most difficult to solve. Perhaps in one sense it should not be referred to at all in this paper. I say this for the reason that the reactions which produce chalking, so far as they have been explained by previous investigators and also by the writer, are purely theoretical. I am speaking of it, however, so that you will know that it has received proper consideration.

Chalking is connected with a loss of gloss which a paint undergoes, that is to say, the antecedent of chalking is loss of gloss. This immediately suggests that loss of gloss and chalking are produced by the same general cause. As to loss of gloss we are pretty sure of its cause. Gloss is due to an excess of oil or binding material, which, lying over the particles of pigment, gives a smooth, even glass-like surface. The binding material in paints, whether it be linseed oil or varnish, is an organic substance,—a substance composed of carbon combined with hydrogen, oxygen, etc. Such organic substances as are used for the binding material in paints are more or less unstable,—they are subject to fairly rapid destruction when exposed to the influence of air, moisture, and sunlight. Loss of gloss is due to this destruction, and it would appear that the chalking of paint is but a step further in this destructive action, whereby the binding material is destroyed, and the pigment becomes loosened on the surface. It may be that in some cases, this destruction of the binding material is superficially accelerated by the pigment or pigments used. However this may be, the proximate cause of chalking is connected with the destruction of the outside binding material in a coat of paint.

Our description of the phenomena of chalking would not be complete if we did not refer to another type of chalking which occurs in the case of certain pigments which are physically unstable. Such pigments appear to change under the influence of moisture from the state in which they were used into a different state, and in circumstances are apparently dissolved out of the paint by moisture, and deposited as a film over the outside layer. I refer here par-

ticularly to the chalking which takes place in the case of basic sulphate of lead, which is a fire process pigment and seems to be peculiarly susceptible to the influence of moisture. I say nothing in derogation of this pigment and would not mention it at all if it were not necessary to make clear the nature of the chalking which occurs at times in its use. To make my meaning clear, I would explain that basic sulphate of lead is one of those pigments which must be kept thoroughly dry, because if this is not done, it will deteriorate very rapidly. We all know that sulphate of lead made by wet chemical processes has very little tinting strength. This is due to its crystalline and relatively coarse structure. It would appear that basic sulphate of lead, when treated with water, changes in structure so as to approach the characteristics of sulphate of lead prepared by the wet process. Also that basic sulphate of lead when used in paint is soluble to such an extent that it becomes changed physically and is dissolved and deposited in its changed form on the surface of the paint. Such a change may or may not take place along with the decomposition of the oil on the surface, such as takes place in the case of ordinary loss of gloss and chalking. It is very often found, however, with basic sulphate of lead paints that if the fine bloom which shows more strikingly in tinted paints is removed the paint is in excellent condition underneath.

Another phase of this question should also be considered. If an elastic paint chalks, it may be that the particles of loosened pigment will be held loosely on the surface, and not be washed away by rain to as great an extent as would occur in the case of less elastic paints.

Whatever the cause of chalking may be, it is objectionable principally because of the tendency of the pigment to come off when touched. There is no question but that it is objectionable from this standpoint. There is another point, however, which must not be overlooked. Paint decay is of many kinds, and one of these many kinds is inevitable. The experience of the users of paint points to the conclusion that most painting jobs will not last in good condition longer than three or four years. This being so, a certain amount of chalking, that is, loss in thickness of coating, is the least objectionable form of decay. For if this loss in thickness does not occur, the result on continued repainting will be the production of so thick a coat of paint that scaling is apt to follow. The fact already mentioned that scaling is more apt to occur with thick layers of

paint than with thin is well verified by experience. Chalking, as it ordinarily occurs, has this further redeeming quality. It nearly always leaves on the surface a roughness, usually called a tooth, which is favorable to repainting.

For the prevention of chalking and loss of gloss, to the extent that this is desirable, we can offer only qualified suggestions. It is evident that what is desired is a vehicle which can be used on the surface of paints that will be more permanent, that is, less destructible than what is ordinarily used. I regret that there is no such material that can be unqualifiedly recommended. I am quite sure that a linseed oil which has been bodied by blowing or real boiling would help in this respect, but here again another danger confronts us. Such an oil, to be satisfactory, should dry sufficiently hard so that it will not be inclined to absorb dirt. The writer remembers using such an oil a number of years ago, with great expectations, but while the oil was less destructible, it remained so soft that dirt readily attached itself to the surface. Sometimes varnish is used in a finishing coat, but so far as I know, this has not prevented loss of gloss or chalking. All that can be said, therefore, is, that if chalking is a defect, it is not an unmitigated evil. Nor is it one that can readily be avoided without other more serious defects arising. You will observe here that I say this with full regard for the plan adopted, that I am not discussing any farther than is necessary for the purpose of this paper, how defects may be corrected by changing the materials used.

Washing—The washing of paint is characterized by the surface of the paint giving up certain water-soluble substances. This is noted in the following ways. The surface, when moistened, rubs up like soap. There is a collection of washed-down pigment at the footings of columns and similar conspicuous places. There are also noted on the ceilings of porches brown spots consisting of substances which have been dissolved out of the paint by moisture, and when the moisture has evaporated, these spots are left, like miniature stalactites or pimples. Apparently washing takes place when a paint contains water-soluble compounds or when water-soluble compounds are formed, either through the reaction of the constituents of the air upon the pigment or a reaction between the pigment and the binding material. Usually a surface that shows washing is found to be in excellent condition underneath. Washing very seldom takes place until loss of gloss occurs. Sometimes, as

in the case of the picture shown here (Fig. 13), the dissolved material will run down near to the edge of a clapboard and on evaporating there, leave a water mark or stain just above the edge.

Washing is less common in the country than it is in large cities, probably due to the greater quantity of sulphur gases present in urban atmosphere.

For the prevention of washing, omitting any reference to the avoidance of the use of those pigments most inclined to wash, the only thing that I can recommend is what I have already recommended in the case of chalking. As washing does not occur to any appreciable extent until the gloss of the paint has disappeared, the

FIG. 13.—Showing the Water Mark Due to Washing near the Lower Edge of the Board.

best method of prevention is to be found in such steps as can be taken to preserve the gloss as long as possible. Washing is apt to give the surface an unsightly and streaked condition, which can usually be quite readily corrected by the application of clean water.

DISCOLORATION—The discoloration of paint is a very large subject, and can be handled in this paper only to a limited extent. We will not discuss the changes in the color pigments, which are more or less directly connected with the pigments used, such as the natural tendency of yellow and red paints to darken, or certain blue paints to fade. These are mostly due to internal changes in the pigment itself. Our subject divides itself naturally into the following heads: spotting, such as when tints turn white in spots; discoloration due to yellowing out of doors; discoloration due to yellowing indoors;

discoloration due to dirt; discoloration due to mildew; discoloration due to sulphur compounds.

SPOTTING—In the spotting of paint, the following characteristics are to be noted. The spots, which may be small or large, are much lighter in color than the remainder of the paint. Such spots show greater chalking than the body of the paint. Moistened with linseed oil, the spots return to practically the original color of the paint, indicating that there had been no destruction of the tinting material, and indicating also that at these spots there had been some excessive destruction or loss of the oil which was originally present. Spots are very apt to appear along the edges of cracks in wood. Sometimes they appear over and around putty, indicating the location of nail holes.

The explanation which I would offer as to the most common cause of spotting is that at the points where spotting occurs, the wood was not completely filled by the priming or body coats. Spotting occurs earlier in two-coat work than in three-coat work. It would appear that although a paint may be thoroughly dry, if portions of the surface painted are not fully satisfied by the priming coat, some of the oil in the subsequent coats may be absorbed by these spots. It may be also that in such a case there is a more rapid internal oxidation and destruction of the oil, due to the excess of air under and back of the spotted places. Whatever the exact features of the cause may be, the remedy is clear. Spotting is to be avoided by the proper filling of the pores of the wood, and by allowing sufficient time between coats for weaknesses to develop that can be corrected by subsequent coats. Spotting will be avoided to some extent by the competent workman using a stiff brush for the undercoats, thereby forcing the paint into the wood.

There is another kind of spotting due to the spattering of lime on wood before it is painted, which lime spots work through the paint and by destroying the oil, show on the outer surface.

DISCOLORATION DUE TO YELLOWING OUT OF DOORS—The yellowing of paint out of doors applies mostly to white paint. The term yellowing is a sufficient description of what takes place. There are two known causes of this kind of yellowing. One is the presence of heavy mineral oil, and the other is the presence of alkalies or alkaline materials. The yellowing of paint due to the presence of heavy mineral oil appears as follows: a mixture of linseed oil and mineral oil if exposed to the air in thin layers, soon becomes clouded,

due to the oxidation of the linseed oil and its separation from the mineral oil. The mineral oil remains practically unchanged. If used in all coats of paint on wood, it exerts a solvent action upon the wood painted, bringing to the surface the gums and other soluble organic material present. Mineral oil itself yellows on oxidation.

The yellowing of paint due to the presence of alkaline materials is explained in this way. Linseed oil soap, which is formed by the action of alkalies upon linseed oil, tends to become a very dark orange on exposure to the air. Linseed oil of itself tends to bleach out during oxidation and become more nearly white. If alkalies are present the oil becomes very much darker, and paint in which the pigment is surrounded by an oil which has undergone such a change will appear yellow.

The prevention of the yellowing of paint out-of-doors, in so far as it is caused in these two ways is by the avoidance of the use of heavy non-volatile mineral oils in paints, and also the avoidance of the presence of alkaline materials. By alkaline materials we refer to those materials which form soluble soaps with linseed oil, such as soda ash, borax, silicate of soda, etc.

Discoloration Due to Yellowing Indoors—The discoloration of paint due to yellowing indoors is a common phenomenon. It has the following characteristics: the yellowing takes place in the dark, and if the object painted can be exposed to the sunlight, the yellowing disappears. In the case of tints, they are changed from the color originally applied. Blue becomes green, and red, if not too deep, an orange, etc. The cause of the yellowing of paint indoors is variously explained, but the one explanation which seems most satisfactory is this. Ammonia is more or less present in the atmosphere. Ammonia turns white paint yellow. (Specimens exhibited.) Ammonia is an alkali, and this action of ammonia is similar to the action of the fixed alkalies referred to in the yellowing of paint outdoors. Ammonia may be used in manufacturing establishments, where yellowing occurs, as in the case of ice-plants. It may be used for cleaning purposes around the premises painted. It may even be generated from the glue size applied to plaster walls, which have not sufficiently matured. It is well known that glue, which is a nitrogenous body, under some conditions gives off ammonia in the presence of alkalies and alkaline earths. Gloss paints are more apt to yellow than flat paints. Linseed oil yellows more than poppy oil. It would appear that the yellowing of linseed oil, as affected by the

pigment used, depends more upon the degree to which the oil is exposed to the action of the atmosphere. The pigment protects the oil more in some cases than in others. The more impermeable paint is less affected by ammonia. A thin coating of varnish over a paint or a little varnish in a final coat will often prevent serious yellowing. The prevention of yellowing, therefore, is all summed up in these words: Have good ventilation, good light, avoid the presence of excessive quantities of ammonia in the atmosphere, and protect the paint as far as practicable by varnish coatings wherever such a treatment is necessary.

Discoloration Due to Dirt—This kind of discoloration of paint, especially white or nearly white paint, is one for which the painter sometimes feels justified in claiming he is not to blame, that the dirt came from outside sources over which he had no control. This attitude is perfectly proper up to a certain point. There still remains the fact, however, that paint will sometimes become dirty more rapidly than exterior conditions would seem to warrant, and to this extent it is a fault of the paint. The dirt, which may accumulate on and stick fast to the paint comes from smoke, ordinary street dirt, the organic matter from growing plants, such as pollen, and the organic matter from decaying plants. Dirt can be carried great distances by the wind and disfigure paint. Discoloration of this kind will occur sometimes in the most inaccessible places. Dirt will collect on roofs, and in the case of storms may be washed down over paint and become attached to it. The examination of paint at very high altitudes greatly removed from smoky chimneys may still show a deposit of smoke and coal dust. The quantity of pollen that is liberated from trees, grasses and many flowering plants is enormous. The fertilization of the seed is dependent upon the wind carrying the pollen and distributing it so that perhaps one particle of pollen in one hundred million is actually serviceable, while the remainder is scattered in all directions. A great deal of this pollen is sticky on its surface. Under the microscope it is shown to possess various forms usually more or less spherical. Decayed pollen massed together appears black, but under the microscope it is observed to be quite translucent and yellow. The conditions favorable to dirt becoming attached to paint are softness and elasticity, conditions which the painter naturally thinks are the best for the paint. Fresh paint is more apt to become discolored by dirt than old paint, simply because fresh paint is more elastic and stickier. After a

rain nearly all paint becomes softer than it was before the rain. Under such circumstances if conditions are favorable, as in the case of the quick drying up of the soil, dirt from roads, etc., may be blown against the paint and remain attached. Some have attributed the increased tendency of paint to become discolored to the increased use of the automobile, which raises clouds of dust on dry days.

The obvious method of the prevention of the discoloration of paint is the use of harder coats, obtained either by cutting down the amount of oil in the paint, or by the use of those pigments which tend to harden the paint. The practical painter must choose between these methods. And here again he may be confronted with the same dilemma, in other words, he may jump from the frying pan into the fire. If by adopting the practice of working towards hard coats of paint he prevent discoloration, he may run into the trouble of cracking and scaling.

A curious instance of the discoloration of paint has been brought to our attention in New Orleans. There they are troubled a great deal with mildew to which reference will be made later, but in addition to this they are troubled a great deal with the dirtying of paint due to dust. New Orleans, within the last ten years has introduced a system of drainage which has resulted in the earth becoming very much dryer than it used to be. During the dry season the soil is dry to a greater depth than formerly. Experiments conducted at New Orleans indicate that the quality of the linseed oil used there affects considerably the tendency of paint to become discolored both from mildew and from dirt. It is found, for instance, that La Plata Linseed Oil, when used in paint in New Orleans, occasions the discoloration of the paint more than North American Linseed Oil. This is clearly due to the fact that North American Oil, when used in paint, gives a harder coating than does La Plata Oil. La Plata Oil has a lower iodine absorption, and it would appear fairly conclusive that only the best quality of linseed oil should be used there and in similar places, and furthermore, that all linseed-oil substitutes made from the semi-drying or non-drying oils should be avoided.

Discoloration Due to Mildew—Discoloration of paint on account of mildew is rather uncommon in the North, but is fairly common in the South. Mildew is a fungoid organism propagated by fine spores, which, when they develop, form a fine network of threads; these threads while black to the eye, are more or less transparent under the microscope. It would appear that in some cases

mildew exists in the wood itself before painting. In other cases its filaments may penetrate the paint and enter into the wood. The ordinary pigments used do not seem materially to prevent the growth of mildew. It would appear that mildew grows better in elastic paints than it does in hard paints, and that moisture and shade are favorable to its growth. Experiments indicate that mildew is killed by the presence of very small quantities of mercury compounds and that a minute percentage of mercurous chloride added to paint will prevent mildew.

We have already suggested the methods which can be used for the prevention of mildew. Mildew is prevented to some extent by the use of paint which forms a hard coating and by the use of the best quality of linseed oil. It may also be prevented by adding to the paint a small percentage of mercurous chloride.

Discoloration Due to Sulphur Compounds—Discoloration due to the presence of sulphur compounds occurs with those paints containing lead pigments. It appears as a brownish or grayish metallic continuous film over the surface of the paint, which film is sulphide of lead and may be readily destroyed by peroxide of hydrogen. Some times this discoloration is due to the intentional or accidental presence in a paint of small amounts of sulphides of the other metals, particularly sulphide of zinc, which may be contained in lithopone to the extent of 30%. The frequent and common use of lithopone in recent years has led to a number of cases where lithopone has been used accidentally with lead paints with resulting discoloration. It is possible that the presence of lithopone in such cases may come from the use of pails for lead paints which pails had previously contained lithopone. Sulphide of zinc in lithopone does not always react with lead pigments to produce sulphide of lead. The danger of such a reaction taking place is, however, so great, that extreme caution should be used against it. In moist places lithopone is more apt to react on lead compounds than in dry places. The discoloration of lead compounds due to sulphur compounds in the air is not as common as one would be inclined to believe from what has been said upon the subject. The only chemical compound in the air which will produce sulphide of lead is sulphuretted hydrogen, which is given off from manure and sewage, and is sometimes found around coal mines and oil wells. Discoloration produced from sulphuretted hydrogen in the air is not usually permanent. Very frequently it will appear in a dry season and then

will entirely disappear after a good rain storm. This is due to the fact that sulphide of lead is rather unstable and tends to oxidize to sulphate of lead.

There are indeed considerable amounts of sulphur compounds in the air of cities and around factories. The sulphur compound most commonly in the air is, however, sulphurous acid, which does not react upon the lead to produce sulphide of lead. Sulphuric acid is also present. Sulphurous acid reacts on lead to form a white insoluble sulphite of lead, which probably oxidizes under favorable conditions to sulphate of lead, also white. The action of sulphurous acid on lead compounds forming sulphite of lead is paralleled by a similar action upon other pigments to form sulphites, as in the case of the formation of zinc sulphite, which readily oxidizes to zinc sulphate, to the formation of which the washing of zinc paints is largely due. Sulphuric acid in the atmosphere forms sulphate of zinc directly.

The presence of sulphur compounds in the air is generally objectionable, and in most cities endeavor is being made to prevent this annoying condition. This is being done by improved sewage systems, high chimneys, and central power plants, as well as by the introduction of hydro-electric power, which avoids the burning of coal. Sulphurous and sulphuric acids are especially active in the corrosion of metals, and those pigments which tend to fix them, that is, form insoluble compounds with them, are in this respect best for the preservation of metals.

There is only one method of preventing the discoloration of paints by the action of sulphur compounds in the air. That is to prevent the presence of such compounds. For the number of lead pigments which it is necessary for the painter to use is so great, that it would seem impossible effectively to prevent discoloration in any other way.

Other Defects—There are other defects, which could be touched upon in this paper, but it is already so long, and the main defects have been so completely treated, that the writer hardly feels justified in extending its length.

Conclusion—The main purpose of this paper has been to consider the question of paint defects without reference, except to a minor extent, to the nature of the materials used. The writer has deliberately taken an attitude of mind which he acknowledges is not a perfect attitude. He admits that the materials used must be con-

sidered in the study of paint defects. At the same time as there has been so much attention given to the question of the effect of materials upon paint defects, with a neglect of the treatment of the subject followed in this paper, it has been deemed necessary to investigate exclusively the other side of the question, in order to more evenly balance the arguments upon the subject. The tendency to connect paint defects with materials has been too great. This paper will serve to some extent to counteract this tendency.

The practice of connecting paint defects exclusively with materials is a destructive practice. Our plan in this paper has been to present a constructive program. No paint material is perfect, but if it is to be commercially judged in comparison with other paint materials, it should be judged at its best and not at its worst. It is the hope of the writer that sometime in the future a new spirit will enter into the discussion of paint materials; that it will be the endeavor of all paint students to find the best way to use paint materials, and if a paint material is in any way defective, to find out how that defect can best be corrected.

CODE OF ETHICS

ARTICLE I.

PURPOSE OF THE CODE:

To define the rules of professional conduct and ethics for the members of the Institute.

ARTICLE II.

THE INSTITUTE EXPECTS OF ITS MEMBERS:

1st. That in all their relations, they shall be guided by the highest principles of honor.

2d. The upholding before the public at all times of the dignity of the chemical profession generally and the reputation of the Institute, protecting its members from misrepresentation.

3d. Personal helpfulness and fraternity between its members and toward the profession generally.

4th. The avoidance and discouragement of sensationalism, exaggeration and unwarranted statements. In making the first publication concerning inventions or other chemical advances, they should be made through chemical societies and technical publications.

5th. The refusal to undertake for compensation work which they believe will be unprofitable to clients without first advising said clients as to the improbability of successful results.

6th. The upholding of the principle that unreasonably low charges for professional work tend toward inferior and unreliable

work, especially if such charges are set at a low figure for advertising purposes.

7th. The refusal to lend their names to any questionable enterprise.

8th. Conservatism in all estimates, reports, testimony, etc., especially in connection with the promotion of business enterprises.

9th. That they shall not engage in any occupation which is obviously contrary to law or public welfare.

10th. When a chemical engineer undertakes for others work in connection with which he may make improvements, inventions, plans, designs or other records, he shall preferably enter into a written agreement regarding their ownership. In a case where an agreement is not made or does not cover a point at issue, the following rules shall apply:

a—If a chemical engineer uses information which is not common knowledge or public property, but which he obtains from a client or employer, any results in the form of plans, designs or other records shall not be regarded as his property, but the property of his client or employer.

b—If a chemical engineer uses only his own knowledge or information or data, which by prior publication or otherwise are public property, and obtains no chemical engineering data from a client or employer except performance specifications or routine information, then the results in the form of inventions, plans, designs or other records should be regarded as the property of the engineer and the client or employer should be entitled to their use only in the case for which the engineer was retained.

c—All work and results accomplished by the chemical engineer in the form of inventions, plans, designs or other records, or outside of the field for which a client or employer has retained him, should be regarded as the chemical engineer's property.

d—When a chemical engineer participates in the building of apparatus from designs supplied him by a client, the designs remain the property of the client and should not be duplicated by the engineer nor anyone representing him for others without express permission.

e—Chemical engineering data or information which a chemical engineer obtains from his client or employer or which he

creates as a result of such information must be considered confidential by the engineer; and while he is justified in using such data or information in his own practice as forming part of his professional experience, its publication without express permission is improper.

f—Designs, data, records and notes made by an employee and referring to his employer's work, should be regarded as his employer's property.

g—A client does not acquire any exclusive right to plans or apparatus made or constructed by a consulting chemical engineer except for the specific case for which they were made.

11th. A chemical engineer cannot honorably accept compensation, financial or otherwise, from more than one interested party, without the consent of all parties; and whether consulting, designing, installing or operating, must not accept compensation directly or indirectly from parties dealing with his client or employer.

When called upon to decide on the use of inventions, apparatus, processes, etc., in which he has a financial interest, he should make his status in the matter clearly understood before engagement.

12th. The chemical engineer should endeavor at all times to give credit for work to those who, so far as his knowledge goes, are the real authors of such work.

13th. Undignified, sensational or misleading advertising is not permitted.

14th. Contracts made by chemical engineers should be subject to the Code of Ethics unless otherwise specified.

ARTICLE III.

For the administration of this Code of Ethics, a Committee on Ethics shall be appointed by the president holding office at the time of the adoption of this Code with the approval of the Council, to consist of five members; one appointed for five years, another for four years, another for three years, another for two years, another for one year, and thereafter, the president then holding office shall appoint one member annually to serve for five years and also fill such vacancies as may occur for an unexpired term. All of these members shall be over forty years of age. The Committee shall elect its own chairman. The Committee on Ethics shall investigate all complaints submitted to them bearing upon the professional con-

duct of any member, and after a fair opportunity to be heard has been given to the member involved, shall report its findings to the Council, whose action shall be final.

ARTICLE IV.

Amendments.

Additions to or modifications of this Code may be made according to Article VIII of the Constitution.

CONSTITUTION

ARTICLE I.

NAME.

This organization shall be termed,

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

ARTICLE II.

OBJECTS.

The objects of this organization shall be:

To advance the cause of applied chemical science.

To give the profession of Chemical Engineers such standing before the community as will justify its recognition by Municipal, State, and National authorities in public works.

To raise the professional standard among Chemical Engineers, discouraging and prohibiting unprofessional conduct.

To coöperate with educational institutions for the improvement of the education of the men who are to enter this profession.

To encourage original work in chemical technology.

To promote pleasant acquaintance and social and professional intercourse among its members.

To publish and distribute such papers as shall add to classified knowledge in chemical engineering and shall increase industrial activity.

ARTICLE III

MEMBERSHIP

SECTION 1. (*Qualifications for Membership.*) Membership shall consist of two grades: Active and Junior.

ACTIVE MEMBERSHIP shall require the following preparation and training:

All candidates must be not less than 30 years of age and must be proficient in chemistry and in some branch of engineering as applied to chemical problems, and must at the time of election be engaged actively in work involving the application of chemical principles to the arts. All candidates for admission to this Institute are expected to have *expert knowledge of at least one branch of applied chemistry.* and must fulfill one of the following requirements:

1. Candidates who hold no degree from an approved university or technical school must have had ten years' experience in chemical technology; five being in responsible charge of operations requiring the elaboration of raw materials, the design of machinery involving chemical processes, or the application of chemistry to industry.

2. Candidates who hold the degree of A. B. (Bachelor of Arts) from an approved university or technical school offering a four-year course must have had at least eight years of practical experience as outlined under No. 1.

3. Candidates who hold the degree of Ch. E. (Chemical Engineer), B. S. (Bachelor of Science), in Chemistry or Chemical Engineering, or E. E. (Electrical Engineer), C. E. (Civil Engineer), or M. E. (Mechanical Engineer), or equivalent degrees from an approved university or technical school offering at least a four-year course, must have had at least five years' practical experience as outlined under No. 1.

4. For candidates who in addition hold the degree of Ph. D. (Doctor of Philosophy) or Sc. D. (Doctor of Science) in Chemistry, the number of years required to earn the higher degree may be deducted from the number of years of experience required.

JUNIOR MEMBERSHIP shall require the following preparation and training:

All candidates must be not less than 23 years of age and must be engaged, at the time of election, in some branch of applied chemistry and must fulfill one of the following requirements:

1. Hold the degree of Ch.E. (Chemical Engineer), B.S. (Bachelor of Science) in Chemistry or Chemical Engineering, E.E. (Electrical Engineer), C.E. (Civil Engineer), M.E. (Mechanical Engineer), or equivalent degree from an approved university or technical school offering at least a four years' course.

2. Have had five years' experience in Applied Chemistry.

Junior Members shall have all privileges of the Institute excepting those of voting, holding office, and wearing the emblem or badge of Active Membership. A suitable emblem or badge of Junior Membership as adopted by the Institute may be worn by the Junior Members. When qualified, a Junior Member may apply for Active Membership, but must do so before reaching the age of 35, otherwise his membership shall expire.

Section 2. (*Applications.*) All applications for membership must be made to the Secretary in writing, and shall embody a concise

statement with the dates of the candidate's professional training and experience, and shall be in a form and in such detail as may be prescribed by the Membership Committee. The applicant for Active Membership shall give the names of at least five members to whom he is personally known. The applicant for Junior Membership shall give the names of at least five persons to whom he is personally known, two of whom shall preferably be members of the Institute. Each of these shall be requested by the Secretary to certify to the training, experience, professional attainment, and standing of the applicant. On receiving a favorable report from at least three of these references, the applicant shall be eligible to recommendation by the Membership Committee.

Section 3. (*Election of Members.*) At stated periods the Secretary shall mail to the members a ballot containing a list of all applicants who have been recommended by the Membership Committee. This list shall contain a detailed statement of each applicant's career and the names of the members who have vouched for him. All ballots shall be returned to the Secretary not later than three weeks after the date of issue. The ballots shall be canvassed by the Membership Committee, who shall report to the Council, who shall then declare each applicant elected for whom at least ninety-five per cent. of all ballots cast are in the affirmative. Provided, however, that any member voting in the negative may address a confidential letter to the Council, stating his objections to the candidate with evidence for the charges made. If the Council upon investigation considers such objections valid, they may declare an election void. A rejected candidate may make application again any time after one year. Persons elected to membership shall be notified at once by the Secretary. They must then subscribe to the rules of the Institute.

Section 4. (*Honorary Members.*) As the result of unusual ability and public recognition on the part of the industrial world, a person may, upon nomination of the Council and a vote of the Society at large, be made an Honorary Member, but at no time shall this number exceed five.

Section 5. (*Expulsions.*) For abuse or misuse of the privileges of the Institute or conduct unbecoming a member in the opinion of the Council, a two-thirds vote of the Council may expel any member of the Institute.

Section 6. (*Dues.*) The entrance fee for Active Members shall be $15.00; Junior Members shall pay no entrance fee; Annual dues

for active members $15.00, for Junior Members $10.00. Junior Members, on becoming Active Members, shall pay an entrance fee of $15.00 less $1.00 per year for each year of their membership as Junior Members. Provided, however, that no entrance fee shall be exacted until the membership shall reach 200.

Any member may anticipate his dues for life by paying in advance such a sum as would be demanded by any reputable insurance association to yield an annuity equal to the annual dues from the time of the agreement until death. Upon resignation, or expulsion, all money so provided is to become the property of the Institute. Any person joining the Institute after the middle of the fiscal year is required to pay one-half of the dues only for that year. Any person in arrears for three months shall be notified by the Secretary. For nonpayment at the expiration of one-half year, a member forfeits the right to vote or to receive the notices of the Association until dues are paid in full. Any member one year or more in arrears of dues may, on vote of the Council, be dropped from the Institute. All members are considered as such unless actual resignations are formally presented and accepted with the full payment of dues. On account of extenuating circumstances, dues may be remitted to any member by a two-thirds vote of the Council.

ARTICLE IV.

OFFICERS.

Section 1. The officers of this Society shall be a President, three Vice-Presidents, a Secretary, a Treasurer, an Auditor, and nine Directors. The officers shall be elected at the annual meeting. The President shall serve one year, the Vice-Presidents for three years each, and the Directors for three years each. The Secretary, Treasurer, and Auditor shall be elected for terms of one year each. At the first annual meeting one Vice-President shall be chosen for one year, one for two years, and one for three years. Three Directors shall be chosen for one year, three for two years, and three for three years. Thereafter, officers shall be chosen annually to serve full terms. The President, Ex-Presidents for the two years succeeding the expiration of their term of office as President, Vice-Presidents, Secretary, Treasurer, and Directors shall constitute the Council of the Institute. The President, Vice-Presidents, and Directors cannot be re-elected within the current twelve months from the expiration of term. The duties of office begin immediately

after election and notification. An acceptance of office must be in writing addressed to the Secretary. Vacancies occurring in any office shall be filled by a majority vote of the Council for the unexpired term. The duties of all officers shall be such as usually pertain to their offices or may be delegated to them by the Council or the Institute.

Section 2. (*Election of Officers.*) After the election at which this Constitution is adopted, the election of officers shall be by letter ballot. The Secretary, at least eight (8) weeks prior to each annual meeting, shall send to every member of the Institute a blank nominating ballot upon which the member may make nominations for the officers and Directors to be elected at the coming annual meeting. The nominating ballot is then to be properly signed and transmitted to the Secretary not later than five (5) weeks prior to the annual meeting. It shall then become the duty of the Secretary to prepare and issue an official ballot upon which shall appear the names of all nominations for office or for Directors which shall have appeared upon at least ten (10) nominating ballots. The official ballots shall be mailed not later than three (3) weeks prior to the annual meeting, one to each member, who shall properly signify on it his choice for the various offices and Directors, and transmit it to the Secretary. At the annual meeting the President shall appoint tellers to whom the Secretary shall deliver all the ballots received by him unopened, and who shall count and announce the vote.

ARTICLE V

COUNCIL

The Council shall have supervision and care of all property of the organization, and shall conduct its affairs according to the Constitution and By-Laws. At each annual meeting it shall present a statement of its proceedings during the year. Eight members of the Council called together by notice from the Secretary shall constitute a quorum, provided, however, that three members may be represented by proxy.

ARTICLE VI.

STANDING COMMITTEES.

The Council shall appoint the following committees:

1. FINANCE.
2. COMMITTEE ON MEETINGS.
3. PUBLICATIONS.

4. Membership.
5. Library.
6. House Committee.

FINANCE COMMITTEE.

The Finance Committee shall have charge of the financial affairs of the Institute. This committee must prepare the budget and approve all expenditures. The Chairman of the Committee may be the Auditor of the Institute.

MEMBERSHIP COMMITTEE.

The Membership Committee shall be constituted of fifteen members, ten of whom may vote by proxy at any meeting. To the Membership Committee all applications for membership shall be referred. It is the duty of this committee to see that no person is admitted to the organization who is not qualified.

COMMITTEE ON MEETINGS.

This committee shall have charge of all meetings of the organization and shall fix dates and places of meeting.

COMMITTEE ON PUBLICATIONS.

This committee shall look after the papers presented to the Institute. If considered expedient, any or all of these papers may be published and distributed to members.

LIBRARY COMMITTEE.

This committee shall have charge of all permanent records, books, papers, pamphlets, etc., and shall obtain and place on file a complete record of all patent literature in reference to chemical engineering.

HOUSE COMMITTEE.

This committee shall look after the social affairs of the Institute, fixing the time and place of entertainments.

ARTICLE VII.

MEETINGS.

The annual meeting of the Association shall be held in December, the exact date to be fixed by the Council.

This Institute shall be governed by its Constitution in conformity with the laws of the United States. All questions shall be decided by majority of votes cast. The Institute shall not be held

responsible for opinions expressed in papers. The name or use of the Institute shall not be tolerated for any commercial purpose.

Upon the adoption of this Constitution officers shall be elected immediately to hold office until the election and installation of their successors.

ARTICLE VIII.

AMENDMENTS TO THE CONSTITUTION.

Any member may propose an amendment by addressing the Secretary. At the first regular meeting thereafter the subject shall be discussed, and if worthy, notice to vote on same shall be posted until the next regular meeting, and written copy of the notice shall be sent to each member. The proposed amendment shall then be discussed in open meeting and can be passed by two-thirds vote of all members of the Institute as the result of letter ballot.

BY-LAWS

ORDER OF BUSINESS.

REGULAR MEETING.

Reading of minutes of last stated meeting.
Miscellaneous announcements.
Reading of papers, discussion, and communications.
Adjournment.

ANNUAL MEETING.

Reading of minutes of last stated meeting.
Miscellaneous announcements.
Stated business.
Annual reports.
Election of officers.
Address of retiring President, etc.
Adjournment.

In all questions requiring parliamentary ruling not provided for by the Rules of the Institute, "Robert's Rules of Order" shall be the governing authority.

OFFICERS AND COMMITTEES FOR 1915

COUNCIL

Elected at Philadelphia Meeting, December 2, 1914

President,
Geo. D. Rosengarten..... Philadelphia, Pa.

Vice-Presidents,
G. W. Thompson..... Brooklyn, N. Y.
A. C. Langmuir..... Brooklyn, N. Y.
John M. Stillman..... Stanford Univ., Cal.

Secretary,
John C. Olsen.....Brooklyn, N. Y.

Treasurer,
F. W. Frerichs..... St. Louis, Mo.

Auditor,
A. W. Smith..... Cleveland, O.

Ex-Presidents,
T. B. Wagner..... New York, N. Y.
M. C. Whitaker..... New York, N. Y.

Directors for One Year

Thos. Griswold, Jr..... Midland, Mich.
Jokichi Takamine..... New York, N. Y.
Jas. R. Withrow..... Columbus, O.

Directors for Two Years

Henry Howard..... Boston, Mass.
John C. Hebden..... Providence, R. I.
Iens P. Lihme..... Cleveland, O.

Directors for Three Years.

Geo. P. Adamson..... Easton, Pa.
J. B. F. Herreshoff..... New York, N. Y.
Samuel P. Sadtler..... Philadelphia, Pa.

COMMITTEE ON PUBLICATIONS

Olsen, J. C., *Chairman*
Gray, Chas. W.
Hart, Edw.
Bain, J. W.
Ittner, M. H.
Cushman, A. S.
Miner, H. S.

MEMBERSHIP COMMITTEE

Langmuir, A. C. *Chairman*
Adamson, Geo. P.
Bassett, W. H.
Converse, W. A.
DeCew, J. A.
Chute, H. C.
Ittner, M. H.
Meade, R. K.
Kaufmann, H. M.
Miner, H. S.
Olney, L. A.
Richards, J. W.
Byers, H. G.
Thompson, G. W.

CHAIRMEN OF LOCAL COMMITTEES ON MEMBERSHIP

Frerichs, F. W..... St. Louis, Mo.
Belden, A. W..... Pittsburgh, Pa.
Lihme, I. P..... Cleveland, O.
Miner, H. S..... Gloucester City, N. J.
Byers, H. G..... Seattle, Wash.
Parker, T. J..... New York, N. Y.
Little, A. D..... Boston, Mass.
Converse, W. A..... Chicago, Ill.

COMMITTEE ON CHEMICAL ENGINEERING EDUCATION

Withrow, Jas. R., *Chairman*
Sadtler, S. P.
Hart, Edw.
Little, A. D.
Wagner, T. B.
Whitaker, M. C.

COMMITTEE ON MEETINGS

Stillman, J. M., *Chairman*
Booth, Wm. M.
Langmuir, A. C
Meade, R. K.
Olsen, J. C.
Sadtler, S. S.
Mason, Wm. P.
Li--me, I. P.

FINANCE COMMITTEE

Toch, Maximilian
Catlin, C. A.
Zinsser, F. G.

COMMITTEE ON MEDAL

Booth, Wm. M., *Chairman*
Richards, J. W.
Reese, Chas. L.
Sadtler, S. P.

LIBRARY COMMITTEE

Alexander, Jerome, *Chairman*
Myers, R. E.
Olsen, J. C.

COMMITTEE ON PATENTS

Baekeland, L. H., *Chairman*
Toch, Maximilian
Grosvenor, Wm. M.
Lee, F.

COMMITTEE ON PUBLIC POLICY

McKenna, Chas. F., *Chairman*
Baekeland, L. H.
Takamine, Jokichi
Frerichs, F. W.
Taylor, E. R.
Wagner, T. B.

COMMITTEE ON CATALOGUES

Grosvenor, Wm. M., *Chairman*
Olsen, J. C.
Wesson, D.
Thompson, G. W.
Marsh, C. W.

COMMITTEE ON ETHICS

Thompson, G. W., *Chairman*, 4 yrs.
Little, A. D., 1 yr.
McKenna, Chas. F., 2 yrs.
Whitaker, M. C., 3 yrs.
Hebden, John C., 5 yrs.

LIST OF MEMBERS, JUNE, 1915

Honorary Member

CHANDLER, CHAS. F., Columbia University, New York City.

Active Members

ACHESON, EDWARD G., Niagara Falls, N. Y.
President, International Acheson Graphite Co.

ADAMSON, GEORGE P., 233 Reeder St., Easton, Pa.
Vice-President and General Manager, The Baker and Adamson Chemical Co.

ADGATE, MATTHEW, Naugatuck, Conn.
Supt. of the Naugatuck Chemical Co.

ALEXANDER, D. B. W., 3814 Santa Fe Ave., Los Angeles, Cal.
Chief Chemist for the General Petroleum Co.

ALEXANDER, JEROME, 502 West 45th St., New York City.
Treasurer and Chemist, National Gum and Mica Co., National Glue and Gelatin Works.

ALLEN, LUCIUS E., Box 22, Belleville, Ont., Can.
Consulting Chemical Engineer; Managing Director Ontario Limestone and Clay Co., Ltd., Belleville, Ont.

ANDERSON, LOUIS J., 129 Lafayette St., Easton, Pa.
Chemical Engineer, Alpha Portland Cement Co., Easton, Pa.

ANDREWS, LAUNCELOT W., 6643 Stewart Ave., Chicago, Ill.

ARNOLD, CHARLES E., 602 West 20th St., Wilmington, Del.

AUSTIN, HERBERT, 485 North Main St., Fall River, Mass.
Chemical Engineer and Partner Manager of Ernest Scott & Co., of Fall River, Mass., and Montreal, P. Q.

AYER, ARTHUR W., 536 E. 41st St., Chicago, Ill.

BAEKLAND, LEO H., Yonkers, N. Y.
Research Chemist and Chemical Engineer.

BAIN, J. WATSON, University of Toronto, Toronto, Can.
Associate Professor of Applied Chemistry.

BAIRD, WM. H., 1199 Woodward Ave., Detroit, Mich.
Gen. Mgr., The Garden City Sugar and Land Co., Garden City, Kan.

BAKER, JOHN T., Phillipsburg, N. J. President, J. T. Baker Chemical Co.

BARR, WM. M., c/o Mallinckrodt Chemical Works, Jersey City, N. J.
Manager, Mallinckrodt Chemical Works.

BARTON, G. E., 227 Pine St., Millville, N. J.
In charge of Laboratory and Dept. Mfg. Glass, Whitall Tatum Co.

BARUCH, EDGAR, 806 Wright & Callender Bldg., Los Angeles, Cal.
Consulting Chemical Engineer.

BARTOW, EDWARD, Urbana, Ill.
Professor of Analytical Chemistry, Univ. of Ill.; Director of State Water Survey of Illinois; Consulting Chemist with the Davenport Water Co.

BASKERVILLE, CHAS., 611 W. 110th St., New York, N. Y.
Professor of Chemistry, and Director of the Laboratory, College City of New York; Chemical Inventor.

BASSETT, WILLIAM H., Cheshire, Conn. Metallurgist, American Brass Co.

BEBIE, J., 1800 South 2d St., St. Louis, Mo.
Chemical Engineer, Monsanto Chemical Works.

BECK, ARTHUR G., care Canada Cement Co. Exchaw, Alberta, Canada.

BECNEL, LEZIN A., 1510 Arabella St., New Orleans, La., P. O. Box 649.
Chemical Engineer and Consulting Chemist.

BEERS, FRANK T., Washburn, Wis.
Supt. Barksdale Plant, E. I. de Pont de Nemours Powder Co.

BEHREND, OTTO F., Erie, Pa.
Vice-President and Treasurer, Hammermill Paper Co.

BELDEN, A. W., c/o Jones & Laughlin Steel Co.,
Aliguippa Works, Woodlawn, Pa.

BERG, HOLGER V., Newport, Del.
Superintendent and Vice-President of The Krebs Pigment & Chemical Co., Newport, Del.

BOOTH, L. M., 136 Liberty St., N. Y.
President and Director, L. M. Booth Co., New York.

BOOTH, WILLIAM M., Dillaye Building, Syracuse, N. Y.
299 Broadway, New York, Consulting Chemist and Engineer.

BOWER, WILLIAM H., 2815 Gray's Ferry Rd., Philadelphia, Pa.
First Vice-President of Henry Bower Chemical Mfg. Co.

BRAGG, CHAS. T., Detroit, Mich.
Technical Director, Berry Bros., Inc., Detroit, Mich.

BRAGG, E. B., Evanston, Ill.
Vice-President and Manager of General Chemical Co., Chicago Branch.

BROOKS, PERCIVAL C., General Chemical Co., Chicago Heights, Ill.
Asst. Supt., Illinois Works, General Chemical Co., Chicago Heights, Illinois.

BYERS, HORACE G., Seattle, Wash.
Professor Chemistry, University of Washington, Consulting Chemical Engineer.

CAMP, J. M., Chief Bureau of Instruction, Carnegie Steel Co., Carnegie Bldg., Pittsburgh, Pa.

CAMPBELL, JOHN HAYES, 161 N. Catherine Ave., La Grange, Ill.
Chemical and Metallurgical Engineer, R. W. Hunt & Co., 2200 Insurance Exchange, Chicago, Ill.

CATLIN, CHARLES A., 133 Hope St. Providence, R. I.
Chief Chemist and a Director of the Rumford Chemical Works.

CHUTE, HARRY O., 197 Pearl St., New York. Chemical Engineer.

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